HAM RADIO

A Beginner's Guide

R. H. Warring

'Ham Radio' is not a universally appreciated term, but, as the author says, it has become an acceptable description of the world of amateur radio, which today has a wide and growing following. Some enthusiasts are content to acquire equipment suitable for listening purposes only, whereas others are not satisfied until they have obtained the resources needed for making their own radio transmissions.

Whatever their aims, this book explains in simple terms something of the technicalities of the subject and the 'language' of amateur radio communication. No attempt is made to cover all the technical ground already covered adequately by many textbooks, but it does deal with transmitting and receiving equipment; its installation and maintenance; the operation of amateur stations; call signs; amateur transmitting licences (with the syllabus of the Ministry of Posts and Telecommunications examination included in an Appendix) and Amateur Radio Call Signs. Transmitting by means of speech and the Morse Code are also described in detail.

Mr. Warring is already well known in his books for his clear exposition of the subject of radio for beginners and once again he has illustrated his work with a whole range of drawings which will help to clarify many aspects of the subject. This is the ideal book for anyone who wishes to master the intricacies of amateur radio broadcasting and to understand fully his subject without the necessity of becoming an expert in the theory of radio and radio construction.

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A BEGINNER'S GUIDE

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INTRODUCTION

That this book is titled as a guide to 'HAM RADIO' calls for an immediate apology. The established amateur radio enthusiast does not relish the term 'ham', as it has an unfortunate connotation. Yet 'HAM RADIO' is the one complete description which means the world of amateur radio to the outsider, or the would-be enthusiast who has yet to start finding out what it is all about. And because this is a book for the beginner and complete novice, that is why this particular title was used.

Basically it is intended as an introduction to the world of amateur radio, a subject which can be confusing in several ways. It is a technical world, utilizing technical equipment, operated in a technical way. That in itself is no barrier to the novice, for the necessary equipment can readily be purchased, and the cost is not necessarily high. As will be shown, an ordinary domestic receiver capable of receiving 'short wave' can be a starting point. But to proceed to the stage where the enthusiast can 'talk' as well as 'listen', a form of qualification is necessary before he (or she) is allowed freedom of the available air spaces for amateur transmissions. This means studying for, and passing, the written examination set by the Ministry of Posts and Telecommunications—which is concerned with technicalities.

The language of the world of amateur radio, too, is quite different from that of everyday life. Even spoken messages use code letters as well as words, for brevity and clearer understanding (once you know what the code is all about!). And telegraphy is all code—not just Morse, but 'code' and 'words' used together. So both the 'spoken' and 'written' messages on the amateur wave bands can be a 'new' language as far as the novice is concerned.

The main aim of this book is to explain both what 'technicalities' and 'language' are all about—and what they mean. There are many excellent textbooks available which deal with technicalities in detail, but they can be heavy going for the novice (and even quite impossible to understand without some previous knowledge of radio technology).

This book aims at bridging the gap between starting from scratch and the normal textbook or advanced treatment of amateur radio subjects. For that reason it tells you *about* circuits, but not how to build or design complete sets (even the majority of experienced amateur radio operators use 'bought' equipment, anyway). It aims at making the whole subject real—and understandable. Skip the sections which have no immediate appeal, and come back to them later. They will then 'make sense', after you have gained a little practical experience, even as just a 'listener'.

CHAPTER 1

THE WORLD OF AMATEUR RADIO

THROUGHOUT the world there are something like half a million amateur radio enthusiasts with their own radio stations, communicating regularly with other enthusiasts in their own country and more distant countries. Great Britain alone contributes some 20,000 amateur radio licence holders to this total. To this figure, however, one must add the tens of thousands of amateurs who merely *listen* to amateur radio broadcasts. They do not have a complete radio station of their own, merely a suitable receiver which only requires an 'ordinary' radio licence to use—not the more technical licence obligatory for amateur radio transmission, to qualify for which the applicant has to pass both a theoretical and practical examination (see Appendix I).

Anyone who has a domestic type receiver capable of receiving the appropriate wavelength (or frequency) of amateur transmissions can thus take part in the world of amateur radio, at virtually no cost—and certainly without having to undergo any special study or training. Once interest has been awakened, however, he (or she) will almost certainly want to acquire a more suitable receiver, erect a better aerial system, and extend both the scope and enjoyment of amateur broadcast reception.

Learning the Morse code will further extend the coverage available by making it possible to take down '*cw*' (carrier wave) or telegraphic transmissions as well as the spoken word, or telephony. Such messages may be difficult to understand at first, with their special use of code letters and abbreviations—introducing the listener to the world of 'radioese'. But these codes are meant to be understood, and are readily learnt—*see* Chapter 9. Apart from the fact that 'radioese' condenses messages sent—and there is plenty of time to translate them after they have been taken down—another advantage is that many of the codes are internationally accepted and mean the same in any country. A difference in languages need be no barrier in '*cw*' transmissions. The

information given starts right with the call-sign itself—again a code which will identify the country of origin (*see* Appendix II).

So interesting (and technically undemanding) can listening to amateur radio broadcasts be that many enthusiasts concentrate on this alone—being generally known by other amateur radio enthusiasts as 'SWL's' (Short Wave Listeners). Some thousands further this interest through membership of the Radio Society of Great Britain, with recognition as amateur *stations*, i.e. 'BRS' (British Receiving Stations) or 'ORS' (Overseas Receiving Stations).

The majority who take up the hobby on this basis, however, usually plan to become a 'full' station and undertake transmission as well to enter more completely into the amateur radio world. Other beginners jump right in at the deep end, as it were, and aim for a Sound Licence A or B as soon as possible. This will entail a certain amount of study and work, and with only two chances a year to take and pass the necessary theoretical examination (*see* Appendix I).

Examination requirements are not very hard. The examinations are not competitive and the questions are straightforward. A pass is much easier to achieve than in the usual academic examinations. In fact, anyone with a genuine interest in the subject should pass first time without any difficulty, provided he (or she) completes the necessary study of the syllabus subjects. Age is no barrier at all. It may be easier to study for examinations in the immediate post-school years of one's life, but a high proportion of people of retirement age achieve equal success in the Radio Amateurs' examinations, even starting with no previous knowledge of radio technology. And they make excellent radio station operators!

There is also an 'option' on the type of licence obtained. Passing the written examination qualifies the applicant for an Amateur (Sound) Licence B, permitting telephony (speech) operation on specific *vhf* amateur band frequencies. A separate practical examination showing a reasonable proficiency in Morse Code sending and receiving is necessary in order to qualify for Amateur (Sound) Licence A, which permits operation in telephony or Morse on all the appropriate amateur bands.

Amateur Radio Bands

In the early days of radio two main broadcast bands came to be recognized—*long wave* with a wavelength from 600 to 2,000 metres;

and *medium wave* with a wavelength of 200 to 600 metres. Radio wavelengths of less than 200 metres were classified as *short wave* and generally regarded as useless for radio transmissions, or limited only to 'line of sight' range.

The short-wave band thus remained relatively free of official and commercial requirements, and was the one exploited by the early amateur radio enthusiasts, until such time as experience and technological advances showed that the short-wave band was, indeed, a most usable range of broadcast frequencies. It was even possible to extend the usable band to far below the limits originally visualized, so that further sub-division was introduced. The short-wave band was defined by the range of wavelengths from 200 down to 10 metres, and rapidly became overcrowded. Still shorter wavelenths, i.e. less than 10 metres, were classified as *vhf* (very high frequency), and again proved usable for special broadcast facilities, television, radar and radio communications.

The ultimate—and inevitable—result was that the whole of the practical radio transmission range, from the upper end of the long wave down into *vhf*, needed some form of protection or control in order to avoid simultaneous use of the same wavelengths by different stations, and consequent loss of intelligibility through interference. As a general rule, the shorter the wavelength the easier it is to achieve separation, the shorter the wavelength of the respective bands, the more these particular bands tend to become filled and overcrowded. There are also other technical reasons why more individual stations can be fitted into the medium wave band than the long wave band, and so on down the scale.

Since the main demand has to meet official and commercial requirements, the availability of 'free' radio space inevitably tends to become more and more restricted as time goes on. There are possibilities in further extension downwards (i.e. even higher *vhf*), although the technical problems involved increase and there are performance limitations (remember that 200 metres wavelength was originally considered the practical minimum for successful radio communication!).

Amateur demand for radio space is met by allocating specific wavelengths on which such transmissions are permitted—and only in these specific bands. Although these may be shared with other services in some cases, this does provide the necessary degree of 'protection', i.e. protection of other broadcasts from interference from amateur

transmissions; and providing radio space for amateur working not overlapped by other major radio transmissions or services. It also enables amateur radio equipment to be designed and built specifically to operate in particular bands, where primary attention can be given to achieving maximum performance at these wavelengths.

The term 'wavelength' has been used so far since the actual wavelength of the radio signal was the original parameter used to define station positions (and allocation to a particular band). This is now (virtually) universally replaced by 'frequency' as more convenient, particularly when dealing with or designating shorter wavelength transmissions.

The relationship between the two is quite simple:

$$\text{wavelength} \times \text{frequency} = \text{velocity of radio waves (the same as the velocity of light).}$$

Since the velocity of light is 300,000,000 metres per second (approx.),

$$\text{frequency} = \frac{300{,}000{,}000}{\text{wavelength in metres}}$$

$$\text{or wavelength in metres} = \frac{300{,}000{,}000}{\text{frequency}}$$

Fig. 1.1 is a simple conversion scale for general use.

Frequency itself is the rate of oscillation of the signal, in units of cycles per second, written cps (a 'cycle' being one complete oscillation). The unit description 'cps' (or c/s) held good for many years, but it has now been replaced by Hertz (abbreviated Hz) in the interest of International standardization. A large number of people, and many publications, still persist in using 'cps' or c/s instead of 'Hz'. This should not cause any confusion since the two mean exactly the same thing. The modern unit 'Hz' is used throughout the remainder of this book for frequency. It can equally well be read as 'cps', if preferred. It is never necessary to write the frequency unit out in full, e.g. 'Hertz', or 'cycles/sec' or 'cycles per second' is quite unnecessary.

Further abbreviations are used to avoid writing a large number of

Fig. 1.1

O's to designate high, or low, numerical values. These are known as *prefixes*, the main ones being

symbol	*prefix*	*factor implied*
G	giga	1 000 000 000
M	mega	1 000 000
k	kilo	1 000
m	milli	1/ 1000 (one thousandth)
μ	micro	1/ 1 000 000 (one millionth)
n	nano	1/ 1 000 000 000 (one thousand-millionth)
p	pico	1/1 000 000 000 000 (one million-millionth)

The prefix is always *written* as a symbol, but spoken in full.
Thus a frequency of 1 000 000 Hz
can be written 1 MHz
and spoken as 'one megahertz' (or 'one megacycle', if preferred).

Special note.

In practice, the use of prefix symbols can differ from the standards given above. For example:

In the case of *resistor values* the capital K is normally used instead of k to designate a factor of 1000. Thus a resistor value is usually written as 4·7 K (i.e. 4,700 ohms), the 'ohms' part being understood.

In the case of *capacitor values*, the use of $\mu\mu$ F may persist instead of pF. They mean the same thing, i.e.

$$\mu\mu = \text{micro-micro or one million-millionth} = \text{pico}$$

If capacitor values are quoted as a number only, then microfarads is the implied unit.

On circuit diagrams, too, the capital P may be used to designate pico (p), but would normally be shown as 'PF' (or pF).

Amateur radio bands are defined by their frequency, usually in megahertz (MHz), or megacycles (Mc/s) because they start at about 2 MHz—*see* Appendix I. The bands worked in the U.K. are as follows

(the wavelength is also given, to save working out when this is of interest):

1·8 MHz (160 metres)

This band is widely used by ships and coastal stations, and other commercial stations, in addition to amateur operators. Range is generally limited to 50–70 miles, particularly in daylight, but more distant stations may be received at night. Atmospheric interference is most noticeable in summer. The best time for listening for more distant stations is in the early hours of the morning in winter.

3·5 MHz (80 metres)

This band is shared with commercial stations broadcasting both Morse and telephony. Range is again generally limited, the most favourable times for listening being the same as for the 1·8 Hz band.

7 MHz (40 metres)

This is a band where transmission and reception is markedly affected by sunspots. When sunspot activity is at a maximum, British stations are mainly prominent (as far as British listening is concerned) during daytime, but with a tendency to fade at night, when more distant Continental stations may be more predominant. Long distance stations are heard best in periods of least sunspot activity, during the early evening hours following dusk, or in early morning.

Powerful commercial radio broadcasts may also be heard on this band, often swamping adjacent amateur transmissions.

14 MHz (20 metres)

This band can provide extremely good range, although not necessarily consistently. It is again markedly affected by sunspot activity, and by time of day. Dusk and dawn are usually the best listening times. European stations can usually be heard at good strength throughout the day, but may fade completely at night during periods of minimum sunspot activity, or during mid-winter.

21 MHz (15 metres)

This band is generally best received during daylight hours, particularly in the spring and late autumn when stations several thousands of miles away may often be heard. The band is, however,

very susceptible to disturbance and listening conditions may vary from day to day. It also has a tendency to fade out soon after darkness falls.

28 MHz (10 metres)

Again a band greatly affected by sunspot activity, and by time of day, but it can have considerable range under favourable conditions. The best listening time is usually winter daylight. Summer daytime tends to be far more limited in reception. The band usually fades completely at night.

70 MHz (4 metres)

A *vhf* band, range of which is necessarily limited because the signals are not reflected back from the ionosphere. Good consistency of performance is usually obtained with ranges of 50–100 miles, but more distant stations can be heard when conditions are favourable.

144 MHz (2 metres)

The lowest permitted frequency for Sound Licence B operators (speech only), with the same characteristics as already described for the 70 MHz *vhf* band.

425 MHz (70 cm)

This is the first of the amateur *uhf* (ultra high frequency) bands which demands the use of specialized equipment. Strictly speaking the range is limited to 'line of sight', but greater distance may be covered under favourable conditions. It is used for contact between local amateur stations, and for amateur television transmissions. A band for the serious radio experimenter.

Other uhf Bands—1215 MHz and above.

These can be regarded as strictly for serious experimental work, demanding expert knowledge of equipment and techniques to work.

A general classification of the various frequencies (wavelengths) in use is:

Short wave or high frequency (*hf*) 1·8*–28 MHz (160–10 metres)
Very high frequency (*vhf*)—70 and 144 MHz (4 and 2 metres)
Ultra high frequency (*uhf*)—425 MHz (70 centimetres)

*The 1·8 MHz *hf* band is also known as the 'top band'.

Types of Transmissions

We have already referred to *telegraphy* (the sending of dots and dashes in Morse code) and *telephony* (ordinary speech) as two different types of transmissions. Both, however, can be sent in different ways, which in some cases may demand the use of special types of communications receivers before the transmission can be heard.

Transmission of a basic radio wave is like sending a single 'note', only the frequency is so much higher than that of an audible note that it cannot be heard, even if picked up and amplified by a receiver. This type of signal is known as a *carrier wave* (*cw*). The usual form of sending telegraphy (Morse) is by using such a single carrier wave only and interrupting it in the required series of dots and dashes, or pulses of carrier wave of different lengths ('dashes' being longer pulses of carrier wave than 'dots'). This is known as class A1 emission (emission meaning transmission), although it is more generally called *cw* (carrier wave) transmission. Because it is a high (radio) frequency signal, such pulses would not be heard in an ordinary type of receiver. The receiver needs an extra circuit to turn the radio frequency pulses it receives into a lower frequency note which can be heard.

Actually, this is not quite true. The interruption of the *cw* in sending pulses does, in fact, modify the actual radio signal in such a manner that some lower (audible) signals are usually produced in the pulsed carrier sent out. These will occur at the beginning and end of each pulse. As a result it may be possible to hear such a signal picked up by an ordinary receiver. But the audible content will not be clear. The dots and dashes will only be heard as a series of 'thumps' which will be difficult, or even impossible, to 'read' as Morse code.

Telephony is distinguished from telegraphy by imposing on the carrier wave the pattern of an audio frequency wave generated directly by the microphone into which the message is spoken at the transmitter end. The resulting mixture of high frequency wave and low frequency audio wave is known as a *modulated carrier* signal. The most common method adopted is to superimpose the 'speech' wave on the 'radio' (carrier) wave in such a manner as to modulate the amplitude of the wave. This is known as *am* (amplitude modulation), and the corresponding class of emission is A3.

To render an *am* signal audible, a receiver has first to pick up the incoming signal and then decode or demodulate it, virtually extracting

the 'audio' content which can then be fed to phones or a loudspeaker. All domestic receivers work on this basis, and so they can pick up and render audible amateur class A3 transmissions, provided the set can tune to the appropriate frequency.

Now telegraphy can also be sent in the same way. That is, sending the dots and dashes in the form of an audio frequency note superimposed on the carrier wave. This is known as class A2 emission. Thus class A2 telegraphy *can* be heard on an ordinary receiver, as proper 'dit-dah' notes. (Instead of 'dots' and 'dashes', the individual Morse characters are normally called 'dits' and 'dahs' in telegraphy, and this description will be used henceforth).

Considering an *am* signal in a little more detail, it is a mixture of a high (radio) frequency and a low (audio) frequency. The frequency of the carrier wave is, in effect, spread out sideways on both sides by the superimposition of the audio frequency – Fig. 1.2. These *sidebands*, as

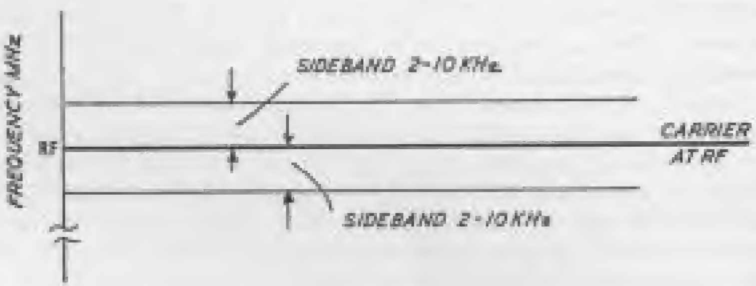


Fig. 12.

they are called, are quite narrow, the diagram being much exaggerated in scale depth to show their presence at all.

For example, a frequency range of about 3,000 Hz is adequate to accommodate all likely speech frequencies. If such a range of audio frequencies is used to modulate a carrier wave of, say, 3 MHz or 3,000,000 Hz, the sidebands will extend 3,000 Hz either side of 3,000,000 Hz, or 'spread' the original carrier only *one thousandth* on either side of its normal (unmodulated) frequency. The effective bandwidth will be from 3,003,000 to 2,997,000 Hz, i.e. a basic radio signal of 3,000,000 Hz frequency, with two sidebands, each of width 3,000 Hz.

Now all the speech content is contained in these sidebands. It is really a waste of power for the transmitter to send the carrier wave as well. Also one sideband duplicates the audio content of the other sideband. So reducing or suppressing the carrier, and eliminating one of the sidebands as well, offers a very efficient form of transmission, known as *single sideband* (*ssb*) working.

This is a modified form of Class A3 working for telephony, and one which is becoming increasingly popular. Again it will be appreciated that it needs a special type of receiver to pick up *ssb* transmission, because the receiver must supply the 'missing' carrier to render the signal in a form where it can be demodulated and heard as telephony.

There are also other types of transmissions, but their application is relatively limited for amateur work and so they need not concern us unduly. The best known is *frequency modulation* (*fm*), which is rather similar in principle to *am* but the frequency of the carrier wave is modulated by the superimposed audio signal rather than the amplitude. Again this needs a special receiver circuit to demodulate. Domestic receivers may include an *fm* band (with appropriate demodulation circuit), as ordinary *vhf* broadcast stations operate on *fm*. On the amateur bands, *fm* transmissions may be used from 1·8 MHz to 22,000 MHz (*see* Appendix I), for both telegraphy and telephony.

The basic advantage of *fm* over *am* is noise reduction at the receiver, all the 'noise' in the circuit being of radio frequency. This can, however, appear as a frequency modulation, although this can be overcome by making the frequency deviation in the signal large. Reducing the frequency deviation, as called for in amateur band working, thus partially nullifies the main advantage of *fm* over *am* (*see also* Chapter 4).

CHAPTER 2

THE SHORT WAVE LISTENER

THE Short Wave Listener (SWL) needs no licence other than an ordinary domestic television or radio licence, and no special equipment other than a suitable radio receiver. 'Suitable' virtually means any radio set capable of receiving short wave transmissions (160 metres down to 10 metres); or *vhf* (4 metres down). But to become a serious SWL—and to get maximum satisfaction from this side of the hobby—demands the use of a more specialized type of receiver than a domestic radio with *hf* and *vhf* tuning bands, and the setting up of an efficient aerial. This is because the amateur bands are relatively narrow and crowded, so that separation on an 'ordinary' tuning dial is difficult. More important still, the strength of signals received on the amateur bands can vary enormously, both with conditions and distance. It needs something special in the way of a receiver to offset these listening difficulties.

These special types of high performance receivers have become known as *communications receivers*. They are not necessarily elaborate or expensive designs, although some are. The primary requirement is that they should provide all the necessary qualities for satisfactory amateur band listening. These qualities are:

1. A high degree of *selectivity* to separate the stations broadcasting in the narrow amateur frequency bands.
2. A high degree of *sensitivity* in order to be able to pick up very weak signals.
3. Good *stability* so that the set does not drift off frequency and so 'lose' a station to which it is tuned.
4. Easy and accurate tuning; and particularly the ability to reset the tuning to any desired frequency.
5. Absence of 'image' or spurious signals, and of self-noise (particularly whistles).

All these features affect the design of the receiver far more than in the

case of an ordinary domestic receiver with its much wider range of tuning. At the same time the 'complete' communications receiver will also need a beat frequency oscillator, or internal oscillator for listening clearly to Morse, or to suppressed carrier telephony.

The choice between 'buying' and 'building' a communications receiver is largely a matter of personal preference—and ability as a practical radio enthusiast. There are a number of relatively cheap ex-government communications receivers which can give excellent listening 'as bought'. Their performance can then be further improved by the addition of a crystal filter, or an external *rf* (radio frequency) preamplifier; or the range extended by the addition of external converter units—*see* Table 1.

Practical designs developed specifically for amateur radio listening are available as plans, in the form of kits, or as professionally built units. Satisfactory construction from kits is well within the scope of any keen amateur with some previous practical experience of radio assembly, and will generally need only a minimum of test equipment to set up. Such receivers can be of valve or transistor type, the latter being more compact and generally much more easy to assemble, as well as working off a small dry battery instead of mains voltage supply. Cost of components can be quite moderate, ranging from as little as £10 upwards in the case of small transistor superhet receivers. At the other end of the scale, many weeks, or even months, of intensive work may be involved in the construction and setting up of a more elaborate and complete communications receiver, with the cost running to ten or twenty times that figure, or more.

Operating a Communications Receiver

The typical communications receiver has a number of controls which will be unfamiliar to the beginner, and an understanding of the basic function and inter-relationship of these controls is necessary in order to get the best possible results. A typical set of controls is shown in Fig. 2.1, as a general guide, although their positions will vary from set to set.

The setting and effect of these controls for receiving normal signals is summarized in Table 2. First the appropriate band is selected and, with the set switched on, the aerial trimmer or *sensitivity* control should be advanced towards maximum. This will 'peak' the noise received on

each band, indicated by the meter needle rising to a maximum as the tuning control is turned to each station (each station will show a peak meter reading at the point of optimum tuning). If the signal is very strong, then the meter needle may approach full scale position, when the sensitivity control needs backing off somewhat. Note that the sensitivity is also affected by the *rf* gain control (*see* Table 2).

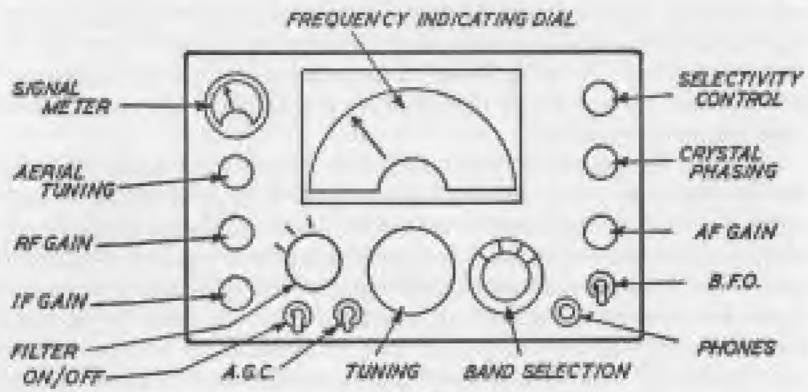


Fig. 2.1

It is now necessary to establish the best balance between *rf* gain and *if* (intermediate frequency) and *af* (audio frequency) gain (the latter two may be combined in a single control). Basically, the greater the *rf* gain the greater the sensitivity and strength of signal fed into the receiver, but this can have two adverse effects. It can make the input signal so strong that it will overload the following circuits causing cross-modulation or 'blocking' and distortion. It can also feed in other unwanted noise. The *rf* gain therefore wants adjusting to an 'optimum' setting where the input signal is adequate, rather than over-strong, when the *af* and *if* gain controls can be adjusted to provide the necessary amplification in the latter stages of the receiver. Note that where a separate *if* gain control is included this is usually most effective in controlling the level of signal or inter-station noise, with the *af* gain control left in about its mid position. The *rf* gain can be 'advanced' or 'retarded' to balance weak or strong signals, respectively.

Further controls may also be available for dealing with interference.

These may comprise a *filter control*, which may or may not reduce the volume appreciably when switched on; a *selectivity* control which narrows the tuned bandwidth (and thus rejects close signals outside the reduced band); or in some cases a *tone* switch. The latter can reduce interference from adjacent stations by being switched or turned to a 'low' position where it accentuates low frequency response, enabling volume to be reduced to reduce higher frequency interference. A similar sort of effect can be demonstrated on an ordinary domestic radio with separate treble and bass controls. 'Favouring' the bass both reduces interference and enables the volume to be reduced.

Transmissions employing suppressed-carrier modulation cannot be received by straightforward tuning. Part of the carrier signals is, in fact 'missing' (i.e. suppressed). Although such a transmission may be tuned in correctly, the signal heard will be very much distorted and unintelligible. To produce intelligibility the receiver itself has to insert the 'missing' part back into the signal received. To do this it must incorporate a separate oscillator which can be brought into effect by operating the *bfo* (beat frequency oscillator) control; or in some designs the *cio* (carrier insertion oscillator) control.

The relevant control set-up is then somewhat different to ordinary *cw* reception—*see* Table 3. The *agc* (automatic gain control) should be switched off and left off and the receiver tuned in the normal way for good strength of signal, even though this is unintelligible. The *rf* gain control should then be turned down, and the *af* gain control turned up to a maximum. The *bfo* control should then be switched on and rotated until maximum intelligibility is achieved, readjusting the tuning slightly if necessary. The success of this depends very largely on the fineness of the adjustments available for tuning and *bfo*, and also on the stability of the beat frequency oscillator. If it lacks stability then frequent readjustment will be necessary to maintain intelligibility.

Alternatively, the *bfo* can be set and left at an optimum position and suppressed-carrier signals tuned in purely on the tuning control. To set the *bfo* control the *phasing control* is turned to about mid-position, the *bfo* turned off and the set tuned in to a steady carrier, as shown by a peak reading of the meter, or maximum volume. The *bfo* control is then operated and adjusted to give a satisfactory 'beat' note. It is really the quality of this 'beat' which governs the quality of intelligibility when tuning on to a suppressed-carrier transmission, and so the

optimum position is merely a matter of the listener's subjective evaluation. Any other note present, when listening, can then be eliminated by slight readjustment of the phasing control.

A tip worth remembering here is that if a filter is also available to reduce interference, and marked loss of volume when the filter is switched in, it means that either the *bfo* control has not been set correctly, or the signal is not properly tuned. In other words, switching in the filter has narrowed the bandwidth (to improve selectivity), but this is now peaking slightly off the signal frequency.

Listening Practice

Rather than haphazard listening—which can be fun for a beginner, but soon loses its novelty—a planned and recorded approach is strongly recommended. This applies not only to number and identification of stations heard, but also the effect of conditions on listening quality and range. Thus daily and seasonal variations generally follow a fairly

DATE	TIME GMT	BAND	STATION HEARD	CALLING	EMISSION	R	S	T	NOTES

Fig. 2.2

regular pattern, particularly on specific wavebands—*see* Chapters 1 and 8. With practice it is readily possible to predict 'best' times for listening to particular transmission bands, and countries—and continue to expand the extent of records. Keeping a log, laid out as in Fig. 2.2, is essential for the serious amateur listener.

SWL's can, in fact, take an active part in the world of amateur radio

for although they are only listening, the fact that a particular signal has been received perhaps at a great distance can be of great interest to the sender of that signal. This applies particularly in the *vhf* bands (70 and 144 Hz) and *uhf* bands (above 425 kHz), where virtually any long distance reception is usually welcome news to the sender.

SWL's, in fact, are encouraged to communicate with transmitting stations they have heard via *QSL cards*, or similar postal replies. What the transmitting station operator really wants to know is:

1. When and where his signal was received.
2. Readability, signal strength and tone (RST).
3. Interference from other stations (QRM).
4. Interference from atmospherics, etc. (QRN).
5. Conditions at the time of reception.

A typical QSL (acknowledgement of receipt of signal) card, as provided by the Radio Society of Great Britain is shown in Fig. 2.3.

To Amateur Radio Station ....
Your .... MHz cw/am/ssb/ ....
received at .... GMT. Date ....
RST .... QRM .... QRN ....
Conditions ....
Receiver .... Aerial ....
Remarks ....
Receiving Station ....
Name and address ....
....

Fig. 2.3

All the relevant information can be filled in (using standard code where appropriate), and the card returned. 'BRS' members of the RSGB can, in fact, qualify for awards by returning enough cards, e.g. the British Commonwealth Radio Reception award for returning cards from fifty call areas in the British Commonwealth. The addresses of amateur transmitting stations throughout the world are published in the *Radio Amateur Call Book Magazine*, available in the U.K. from Short Wave Magazine Ltd.

Only a proportion of the logged entries will be sufficiently interesting

technically, or on other merit, to justify a QSL card, or a similar postal reply to a transmitting station. There are really no hard and fast rules on this subject (other than special requirements laid down by the RSGB as qualifications for particular awards to radio listeners); but Table 4 can be used as an initial guide.

Table 1. Use of Additional Receiver Sections

Addition	*Effect*	*Notes*
CRYSTAL FILTER	Reduces spurious signals and interference by narrowing bandwidth.	May already be incorporated in a standard communications receiver
EXTERNAL *rf* PREAMPLIFIER	Improves selectivity and sensitivity.	
EXTERNAL *rf* PREAMPLIFIER CONVERTER	Extends tunable frequency range and improves high frequency stability and/or selectivity	Preferred types: high stability *hf* converter or crystal controlled *shf* converter.
EXTERNAL FREQUENCY CHANGER COUPLED TO RECEIVER *if* (followed by *if* amplifier)	Improved selectivity.	Also known as a 'Q-multiplier'.
PEAKED AUDIO FILTERS	Improved *cw* reception.	
NOISE LIMITER	Chops off peaks of interference.	
ATTENUATOR	Reduces cross-modulation.	Particularly with narrow band operation.

Table 2. Use of Controls

Control	*Setting*	*Remarks*
AERIAL TRIMMER (SENSITIVITY)	Set to peak noise received on each band.	Direct sensitivity control.
rf GAIN	Maximum—sensitivity high.	Stronger signals will tend to cause cross-modulation and blocking.
	Minimum—maximum amplification from *af* and *if* gain controls. Optimum—towards maximum setting.	Sensitivity reduced.
af GAIN*	About half way or less maximum—for reception.	Usual optimum—reduce to prevent overloading.
if GAIN*	Vary as necessary.	Control of level of signal noise.
agc	Off for *cw* reception for maximum sensitivity.	Can be switched on after fine tuning.
bfo	For maximum intelligibility	

*These may be combined in one control.

Table 3. Reception of Suppressed Carrier Signals

Step	*Action*	*Remarks*
1.	Switch off *agc*.	
2.	*af* gain turneded up to maximum.	
3.	*rf* gain turned down to less than half way.	
4.	Tune in for maximum signal strength.	Signal will be unintelligible.
5.	Turn on *bfo*.	Adjust *af* gain and *if* gain as necessary to prevent overloading and distortion.
6.	Adjust *bfo* until signal becomes intelligible.	

Table 4. Likely QSL's of Interest (Received in U.K.)

Transmitting Band (MHz)	*Conditions*
1·8	Range of more than 150 miles in daytime. Range of more than 500 miles at night.
3·5 – 7 – 14	More distant European stations.
21 – 28	Overseas stations (outside Europe).
70 – 144	Range of more than 50 miles.
above 425	Range of more than 25 miles.

Special note. It is illegal to listen to police, fire brigade and other public service broadcast messages; in fact, it would appear to be illegal to listen to any radio transmission not specifically intended for the listener, as opposed to general broadcasts and amateur transmissions. The law is obscure, and difficult to interpret on these points. In fact it can be virtually meaningless in many respects. Nevertheless, there are the odd prosecutions which appear from time to time, directed against people who have listened to police or fire brigade messages – usually on domestic radios.

CHAPTER 3

TELEGRAPHY (MORSE)

TELEGRAPHY is 'written' transmission, using code symbols (Morse). Transmission rate can be anything up to about sixty words per minute (about a third the rate of voice transmission), although the usual rate of working is appreciably lower. Twenty words per minute is probably a typical average in amateur practice, and a target for the novice operator to achieve with consistency.

Speed is not all-important in sending. Because the transmission is 'written'—even if only in terms of 'dits' and 'dahs'—any transmission will carry the characteristics of the operator's 'fist', as well as the quality of his equipment. This character will develop with continued practice, but the primary requirements remain:

1. Accuracy, so that the message comes through clean without errors or corrections. Accuracy is *far* more important than speed.
2. A steady and uniform rate of sending. This is much easier to read than a message which is continually changing its pace.
3. Even spacing so that individual letters are readily identified rather than run together.
4. Good technique in the use of codes.

Even the experienced operator can be guilty of one or more of these faults if he lets his technique get sloppy. The novice can only work up to a suitable standard by continual practice—and try to work up his speed at the same time. Sending speed, in fact, is probably less important than reading speed. Really to enjoy telegraphy an operator needs to work up to a receiving speed of at least twenty-five words per minute, with a capability to read the message directly in his head rather than writing it down (even if he may prefer to write it down). Logically, once this familiarity with the code has been obtained, sending speed should be of a similar order, but in practice this may be limited by physical and equipment factors.

Obviously practice transmissions are best kept off the air (although

there are regular slow speed practice transmissions broadcast on which one can practice listening—*see* Chapter 1). The traditional practice set is the key and buzzer circuit—Fig. 3.1. This can also be used to generate

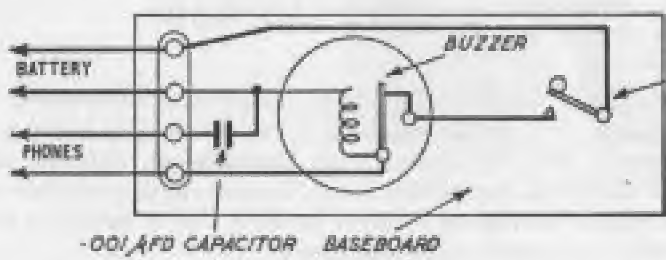


Fig. 3.1

a typical note in phones, which is preferred as being more realistic than listening directly to the buzzer sound. The strength of the signal received in the phones is determined by the value of the capacitor used. If too loud, the value of the capacitor should be reduced.

Alternatively the code-practice set can comprise a simple audio frequency oscillator turned on and off by the key. The simple valve circuits originally used for such sets have now largely given way to even simpler transistor circuits—very easy to make, compact, and working off a 1·5 or 3 volt dry battery. Fig. 3.2 shows such a circuit which can be

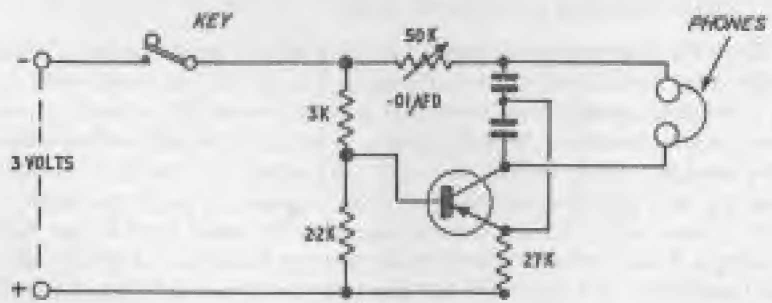


Fig. 3.2

used with any high impedance phones. Virtually any general purpose

af transistor will do. The potentiometer is included to act as a volume control, and will also have some effect as a tone control.

The correct operator position for good sending is shown in Fig. 3.3.

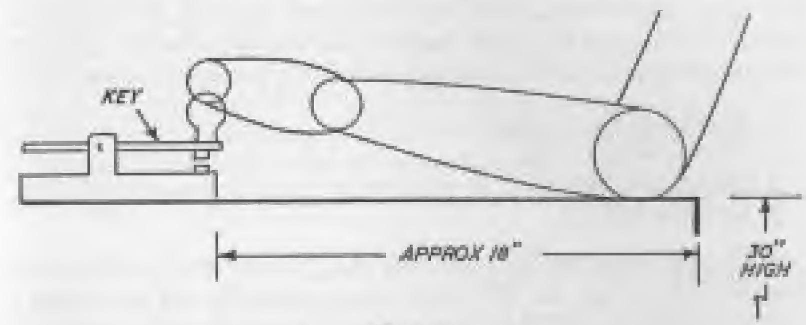


Fig. 3.3

The key is placed far enough in from the edge of the table for the elbow to rest on the table, the operator sitting with the right shoulder and arm in line with the key.

The key itself will have three adjustments. Initially the spring tension should be set to be quite heavy, and the back adjustment set so that the key has about $\frac{1}{16}$ in. movement. The third adjustment is merely for aligning the contacts laterally. These side screws should be set so that there is little or no sideplay.

The key should be held lightly for sending, with the thumb on the left of the knob and the first and second fingers on the top and other side of the knob, respectively. The grasp on the knob should be firm, but not tight or cramped. Key movement is then accomplished with a wrist action, the wrist always being free of the tabletop. This will develop a 'natural' action, free from tightness or jerky sending. Always keep hold of the key knob—never 'tap' it.

Once this has been mastered the spring tension can be reduced, using only the minimum tension necessary to make the key open immediately the downward pressure on it is released. This will make the key less tiring to operate over longer periods. The free vertical movement of the key can also be reduced slightly, if desired (or thought necessary to improve speed), but the movement should never be reduced below $\frac{1}{32}$ in.

Keying the Transmitter

Exactly the same type of key is used for sending via a transmitter, the key being connected directly into a suitable part of the transmitter circuit, together with a click filter as necessary (*see* Chapter 4). Basically any stage of the transmitter can be keyed although it is common practice to insert the key in the final valve circuit of the power amplifier. The alternatives available can apply at any stage, however, these being:

1. Anode circuit keying.
2. Blocked-grid keying.
3. Screen-grid keying.
4. Cathode keying.

With *anode keying* the key interrupts the *ht* supply to the anode of the selected valve. This has the disadvantage that the full *ht* voltage is broken by the key, and is in fact developed across the key contacts. To isolate the operator from this it is highly desirable, where high power is involved, to use the key to operate a relay so that only low power is carried by the key contacts, the full *ht* being 'made' and 'broken' only by the relay contacts—Fig. 3.4A.

In any case some sort of filter circuit will be needed across the *ht* circuit contacts (whether key or relay), both to provide click suppression and spark quenching. Such a filter circuit can comprise an inductance (L) in series with the line, and a resistance (R) and capacitance (C) in series across the contacts—Fig. 3.4B. The inductance is

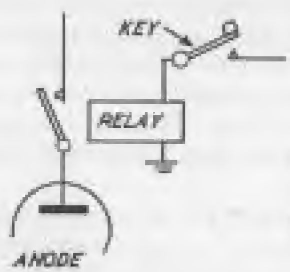
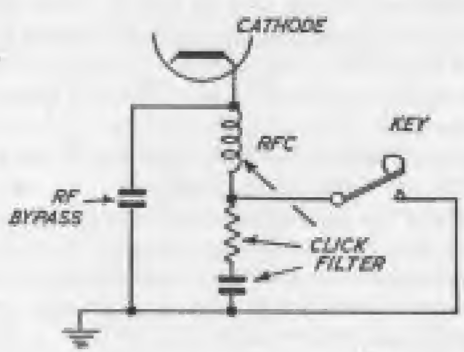


Fig. 3.4A



3.4B

then effective in controlling the rise of the anode current when the contact is closed; the capacitance provides quenching on 'break', and the resistance controls the rate of discharge of the capacitor on the subsequent 'make'.

All three values have, therefore, to be chosen carefully in order to achieve the desired result, and at the same time provide a suitable shape for the keyed envelope. An additional inductance may sometimes be added on the other side of the key (contacts), in which case it may be possible to eliminate the resistor as the two inductances themselves can provide sufficient control of the capacitor discharge.

Blocked-grid keying is shown in Fig. 3.5. Here sufficient negative bias

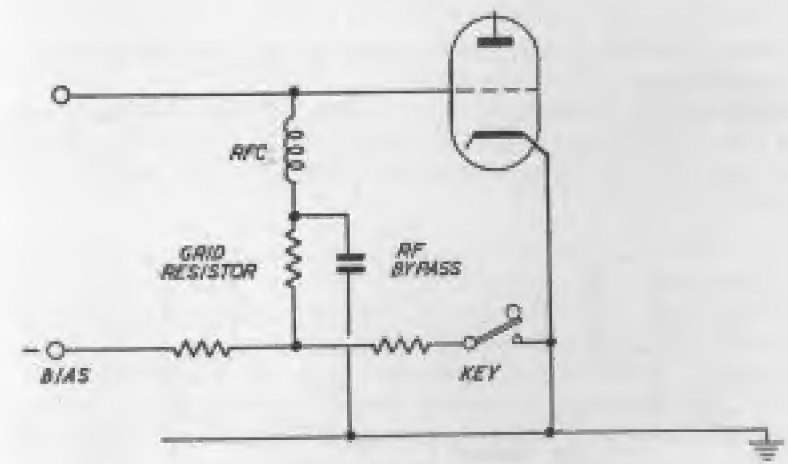


Fig. 3.5

voltage is applied to the grid to cut off the anode current when the key is open, removing this 'blocking' bias when the key is closed. The bias required may be anything up to five times the cut-off in order to ensure that there is no *rf* output from the valve, with the key open. Again click filter elements are shown incorporated in the circuit.

Screen-grid keying offers the possibility of a simpler circuit, merely breaking the *ht* supply to the grid—Fig. 3.6. It may, however, be necessary to supply some negative bias to the grid in the key up position

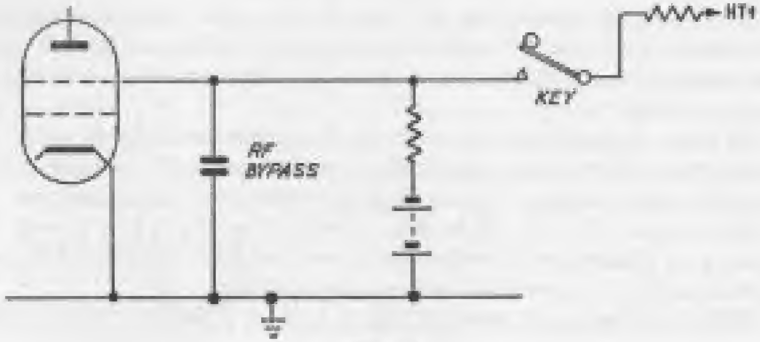


Fig. 3.6

to ensure that there is no anode current in this condition, and thus no *rf* output until the key is depressed.

Cathode keying is shown in Fig. 3.7. This is virtually similar in effect to anode keying and follows a similar configuration as regards click filtering. The latter is less effective in oscillator circuits than amplifier circuits.

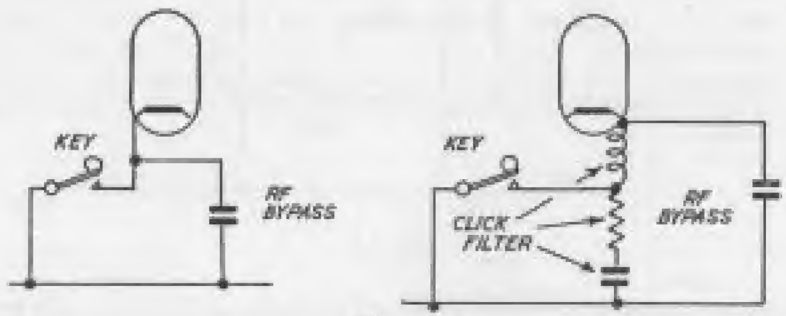


Fig. 3.7

Various other keying possibilities exist. For example, keying is sometimes applied in the power supply itself, either in the secondary circuit, or the primary. Both demand the use of a well insulated keying relay. Certain advantages are claimed for such systems, although they are not much used these days. They suffer from inherent keying lag because of

the time constant of the smoothing filters in the power supply output circuit.

Keying the oscillator offers certain advantages, and is virtually necessary for 'break-in' keying. This takes advantage of the fact that since there is no transmission during intervals between sending, a receiver can be left to operate continuously and thus receive incoming signals during these intervals. This can make for speedier operation. For example, if an operator has failed to read a part of a message correctly he can immediately hold his transmitter key down to 'break in' and indicate the fact without further loss of time.

The basic requirement for break-in operation is that during intervals the oscillator produces no interference at all in the receiver. The direct solution to this is to switch the oscillator off during such intervals—which is what applying keying to the oscillator stage does. Unfortunately it is more difficult to eliminate 'chirps' on an oscillator stage than an amplifier stage. Also the method adopted for keying may produce changes in frequency of the oscillator. Satisfactory oscillator keying for break-in operation, therefore, may demand the use of more specialized circuits, particularly at higher frequencies. One relatively straightforward solution (but with limitations) is sequence keying, using the back contacts of the key to key the oscillator circuit and the front contacts to key the power amplifier circuit. The power amplifier is then turned on a short interval after the oscillator, and turned off momentarily before the oscillator—the resulting time lag when the power amplifier is 'off' (and thus there is no emission) covering the period during which the keyed oscillator is developing 'chirps' or 'clicks'. Similar, and alternative, solutions can be derived electronically.

Electronic Keyers

Continual operation with a manual key at speeds much in excess of twenty words per minute can become extremely tiring, leading to a deterioration of the 'fist', although skilled and well practised operators can maintain even higher speeds without difficulty. A better solution for fast sending, however, is the use of electronic keyers, known generally as 'bugs'. Basically these are of two types: the semi-automatic keyer which derived largely from landline telegraphy; and the fully electronic automatic keyer, known as an 'el-bug'.

The 'bug' incorporates a weighted spring, vibrating against a contact.

The rate of vibration can be controlled by sliding a weight up or down the vibrating arm. This vibrating arm supplies the 'dit' signals automatically when the key is moved to one side. 'Dah' signals are made manually by the operator, moving the key to the opposite side.

The 'el-bug' is fully automatic and comprises, basically, electronic circuits producing continuously a series of regular 'dits' and a series of regular 'dahs'. All the 'dits' are of equal length and equally spaced. The 'dahs' are each three times the length of a 'dit' and spaced by the length of a 'dit'.

The key is simply a double-throw switch, spring loaded to its central position. Movement to one side closes the contact to select 'dits'; and movement to the other side selects 'dahs'. In each position 'dits' or 'dahs' are passed by the key for as long as the contact position is held (Fig. 3.8).

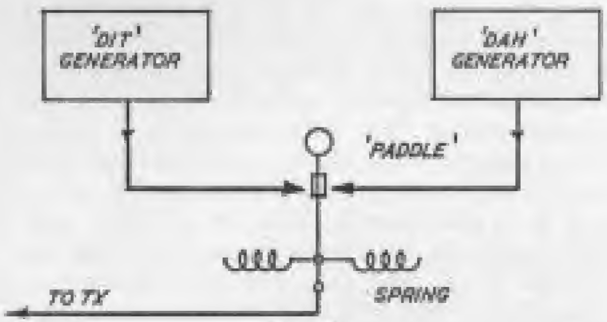


Fig. 3.8

Speed of sending is thus virtually limited only by the speed at which the operator can read—although the only way an operator can tell what he is sending is to listen to it in a monitor. The technique of electronic sending is, therefore, quite different to ordinary keying. It demands an ability to be able to read Morse directly without writing it down—at the desired sending speed—and to co-ordinate the key action to select exactly the required number of 'dits' and 'dahs' in correct sequence. One cannot switch readily from manual keying to automatic keying. Considerable practice is necessary to master this quite different technique and build up speed.

Fully automatic electronic keyer designs range from the relatively simple to quite complex computer-type circuits. Valve electronic keyers have now largely given way to transistorized circuits, one particularly popular design being shown in Fig. 3.9. The variable resistors enable

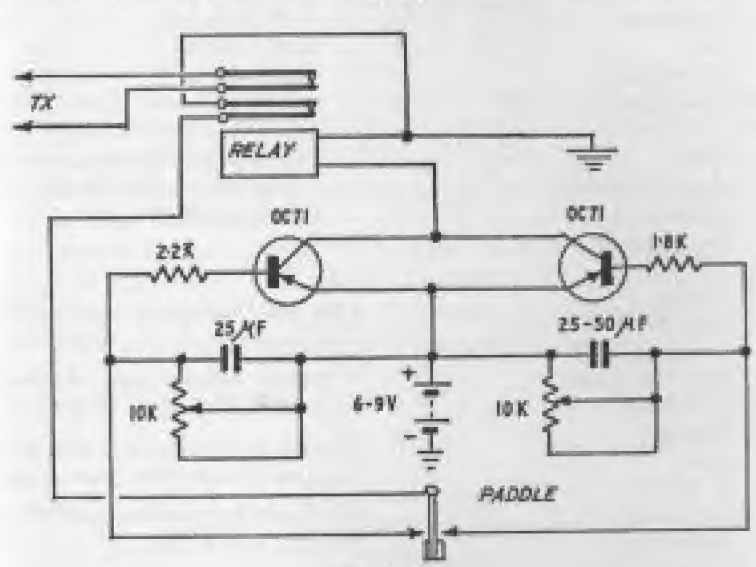


Fig. 3.9

the speed at which the 'dits' and 'dahs' are generated to be varied for operating speeds between about three and thirty-five words per minute. A G.P.O. type 600 relay or any similar low resistance relay is suitable, using almost any type of general purpose *af* transistors (e.g. OC71).

THE MORSE CODE

A di-dah
B dah-di-di-dit
C dah-di-dah-dit
D dah-di-dit
E dit
F di-di-dah-dit
G dah-dah-dit
H di-di-di-dit
I di-dit
J di-dah-dah-dah
K dah-di-dah
L di-dah-di-dit
M dah-dah
N dah-dit
O dah-dah-dah
P di-dah-dah-dit
Q dah-dah-di-dah
R di-dah-dit
S di-di-dit
T dah
U di-di-dah
V di-di-di-dah
W di-dah-dah
X dah-di-di-dah
Y dah-di-dah-dah
Z dah-dah-di-dit

1 di-dah-dah-dah-dah
2 di-di-dah-dah-dah
3 di-di-di-dah-dah
4 di-di-di-di-dah
5 di-di-di-di-dit
6 dah-di-di-di-dit
7 dah-dah-di-di-dit
8 dah-dah-dah-di-dit
9 dah-dah-dah-dah-dit
0 a long dah, or dah-dit, or dah-dah-dah-dah-dah

Note.
One 'dah' should be equal to three 'dits' in length.

The space between parts of the same letter should be equal to one 'dit'.

The space between two letters should be equal to three 'dits' (or one 'dah').

The space between two words should be equal to six 'dits'.

CHAPTER 4

TRANSMITTERS

TRANSMITTERS are based around a radio frequency *oscillator* or 'generator' of an *rf* signal. This will require a *power input*. Such a basic combination, with the oscillator output taken to an aerial, will form a complete, if simple, transmitter capable of radiating a continuous carrier wave (*cw*) signal, at a frequency determined by the oscillator. If the latter is fixed (e.g. as in the case of a crystal controlled oscillator), then the addition of a key capable of breaking and making the oscillator output will complete a 'working' transmitter capable of sending a series of 'on-off' *cw* signals at a fixed frequency—Fig. 4.1.

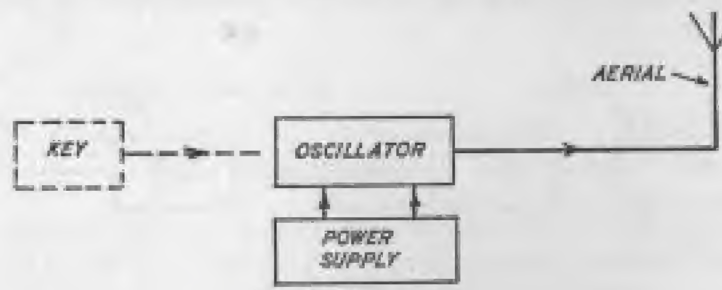


Fig. 4.1

This is the simplest form of Morse transmitter which is capable of giving quite good results, provided the oscillator circuit can be made stable. Apart from suitable design being a primary requirement, the power input which can be utilized without heating effects interfering with stability of operation is usually limited. Also the efficiency of such a transmitter is relatively low. Very much better efficiency and a 'cleaner' signal can be produced by restricting the power input to the oscillator and following this by a *power amplifier* to boost the actual signal applied to the aerial—Fig. 4.2. If necessary, more than one *rf* amplifier can be introduced, connected in series.

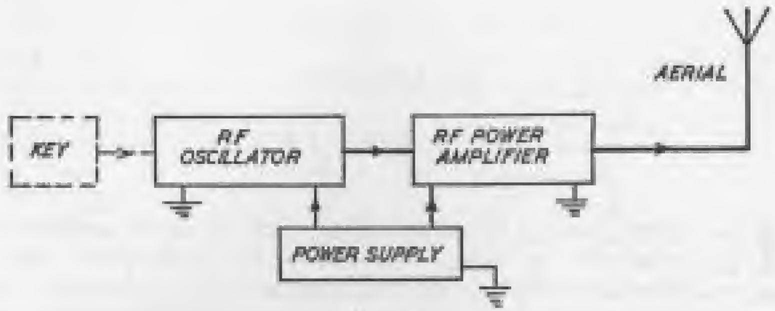


Fig. 4.2

To extend the working of the transmitter the oscillator can be made tunable, so that it can generate a range of *rf* frequencies (variable frequency oscillator). At the same time, to 'adjust' the aerial to the efficient handling of such frequencies a tuned circuit, known as a *tank circuit*, is added—Fig. 4.3. This set-up may be further improved by the

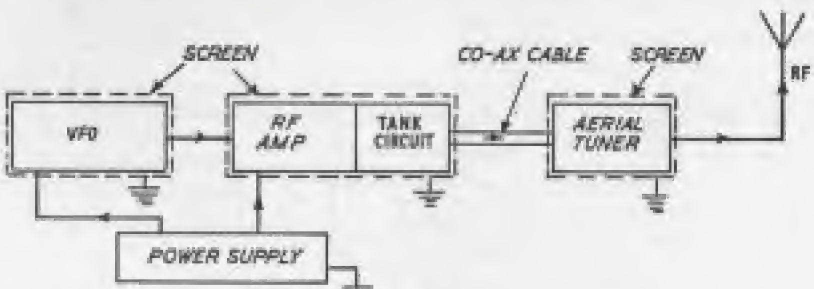


Fig. 4.3

addition of an aerial tuner when the tank circuit virtually becomes an *rf* transformer. This considerably simplifies the transmitter design since regardless of the characteristics of the aerial the aerial tuner can be adjusted so that the tank circuit will always be supplying power to the same load. In practice the tank circuit is formed by the anode circuit of the power amplifier and so need not be regarded as a separate entity. The description 'tank circuit' is equally applicable to any resonant circuit in any transmitter stage.

A number of other refinements are then possible. For example, making the oscillator fully tunable can introduce stability problems. It is easier to achieve stability by restricting the variable frequency range. To extend the frequency range available it is then a relatively simple matter to double, treble, etc., the original frequency with a *frequency multiplier*. This fits in very well with amateur band requirements where the bands are simple multiples of each other. Thus a variable frequency oscillator (*vfo*) designed to cover only the 3·5 kHz band can also provide M
cw signals in the 7, 14, 21 or 28 Hz bands by incorporating a frequency multiplier between the oscillator and *rf* amplifier—see Fig. 4.4.

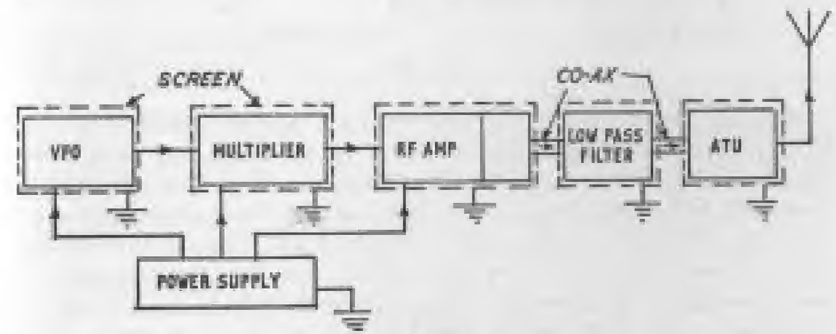


Fig. 4.4

This block diagram also shows an additional unit between the tank circuit (anode circuit of the power amplifier) and the aerial tuner, marked *lpf* or *low pass filter*. The object of this is to produce a 'clean' signal by filtering out any harmonic contents, and thus minimize any interference with adjacent signals. Part of this job is already done in the tank circuit but the fact that many amateur transmissions are on bands adjacent to television transmissions places a premium on interference suppression. This also affects the actual construction of the set, particularly as regards screening requirements and the necessity for eliminating long lengths of wiring.

Further consideration now has to be given to the manner in which the oscillator is *interrupted* (for sending Morse or telegraphy); or *modulated* (for sending speech or telephony). These are type A1 and type A3 emissions, respectively.

Morse signalling (A1 emission) is obviously the simpler of the two since this only requires that the *rf* output from the oscillator be interrupted at some suitable stage by means of a mechanical key so that the *cw* signal is put out in the form of long and short bursts with intervals of no signal between—Fig. 4.5.

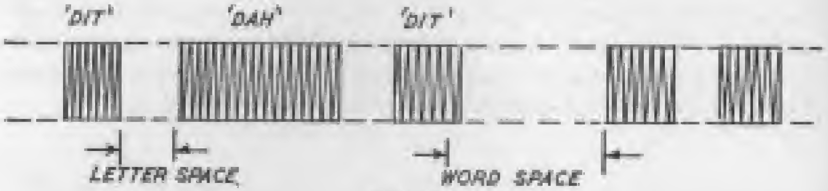


Fig. 4·5

Basically such a signal consists of a series of 'square' waves—Fig. 4.6. Whilst these have the desirable effect of providing an intelligible signal, they also have unwanted side effects, notably the inclusion of unwanted 'sidebands' in the resulting envelopes. These can spread over adjacent frequencies, even a whole amateur band. Thus other receivers tuned to near frequencies may also hear the signals as 'interference', or more usually in the form of 'clicks'. To avoid this it is necessary to introduce a *click filter* in the keyed circuit of the transmitter. This reduces sudden changes in amplitude in the *rf* signal, which are responsible for the 'sidebands', and rounds off the pulse envelopes as shown in the second diagram in Fig. 4.6.

Fig. 4.6

It will be appreciated that this rounding and re-shaping of the keyed *rf* signal will also affect the quality of the Morse signal heard. There will be an optimum form of envelope where sideband effects are at a

minimum and the signal is clear and distinct. If the envelopes are distorted the individual signals will be less distinct and may even tend to run together or blur.

The preferred type of envelope is one which is fairly 'solid' on the 'make' end of each envelope, with a softer 'break'. Thus any click present occurs at the start of the signal with, ideally, no click as the key is opened. This produces the most acceptable 'dit' or 'dah' for listening.

In the case of speech or A3 emission the final signal is produced by superimposing an audio frequency (*af*) signal on the *rf* or carrier signal, yielding a modulated *rf* signal—Fig. 4.7. This final signal will actually

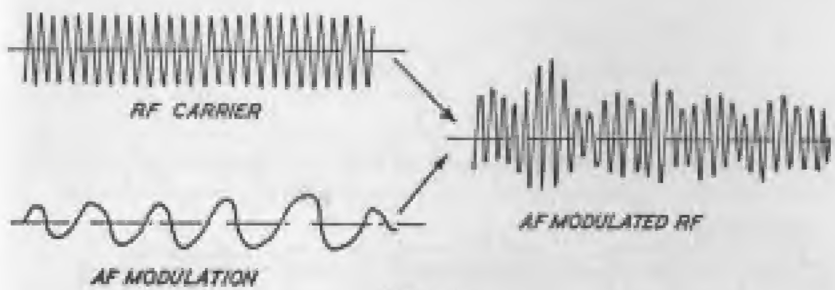


Fig. 4·7

comprise the original carrier frequency, say f, together with two sideband frequencies of f+m and f−m, where m is the frequency of the modulating signal. The complete signal will thus have a spread or bandwidth of 2m Hz about a centre frequency of f. It is obviously necessary to keep this spread to a reasonable minimum. Thus 1 kHz is a typical modulating frequency used, which would give an effective bandwidth cover of 2 kHz. However, modulation frequencies in use may well extend up to 5 kHz, covering a total bandwidth of 10 kHz.

As a general rule, all speech frequencies can be encompassed within a frequency range of about 2,000–3,000 Hz. For telephony, therefore, there is no necessity to employ sidebands with a spread of more than 3,000 Hz—say a total bandwidth of 5–6 kHz. For general broadcasting, which includes music as well as speech, a considerably wider bandwidth is required in order to accommodate the higher audible

frequencies without 'clipping' or distortion, e.g. logically up to the upper limit of audibility or around 15,000–16,000 Hz. Broadcast stations, therefore, operate with a much wider bandwidth than amateur radio transmitters. They occupy more 'air space' as a consequence—and tune in over a broader range.

The *af* or speech signals are derived directly from a *microphone*. These signals are very weak and thus require amplifying before being fed into the main transmitter circuit to modulate the *rf* or carrier wave signal. With simple amplitude modulation (A3 emission) the favoured way is to apply the amplified *af* signal direct to the anode circuit of the *rf* power amplifier via a modulation transformer—Fig. 4.8. This also has

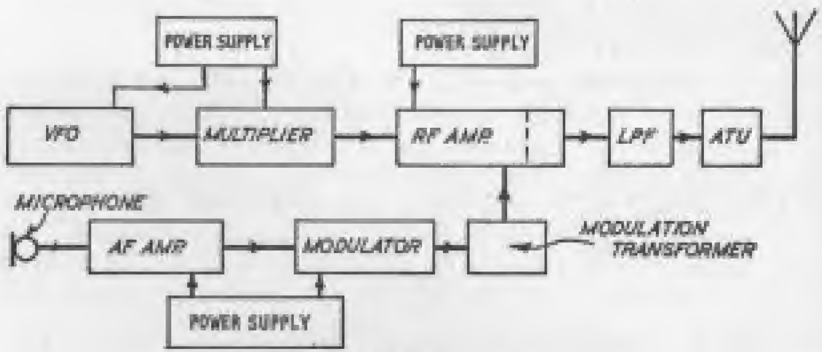


Fig. 4.8

the advantage of increasing the *rf* output power since extra power is supplied to the output circuit via the *af* amplifier. Special circuits may also be included to compress the *af* band, apply speech clipping by controlling the shape of the waveform, and suppress higher frequencies to restrict the range of sidebands radiated.

Sideband (Suppressed Carrier) Transmissions

Whilst simple amplitude modulation provides a satisfactory and relatively straightforward method of providing speech transmission on amateur radio bands more and more attention has been given during recent years to the development of *sideband* transmission where the carrier wave itself is suppressed. Although this demands more complex

circuits and more expensive critical components it has several advantages, notably much higher efficiency and an appreciable reduction in the bandwidth occupied by the signal.

It has already been noted (e.g. *see* Chapter 1 and Fig. 4.7) that the simple form of *af* speech transmission comprises a carrier with two sidebands each the mirror image of the other and spreading over the *af* frequency range covered. All the '*intelligence*' needed is contained in the sidebands, whilst the majority of the *power* is contained in the carrier. If the carrier is suppressed this power can be saved and all the transmitted power contained within the sidebands—Fig. 4.9.

Fig. 4.9

In this form the transmission is known as double sideband suppressed carrier (*dsb*). Any conventional *am* receiver can be modified to receive such transmissions, 'tuning' to either sideband, the chief modification being that the receiver must also supply and inject the 'missing' carrier before the sideband signals can be made intelligible. As the carrier is suppressed at source (i.e. at the transmitter), signals received can be very much stronger for the same input power. On the other hand the bandwidth occupied is exactly the same as if the carrier were present (i.e. the same as for conventional *am* transmission).

This principle of operation can be carried one stage further by suppressing one of the sidebands as well as the carrier, yielding single sideband transmission (*ssb*). This has all the advantages of double sideband transmission plus the fact that still more power can be put into the

'intelligence' signal (since only one sideband is involved instead of two): and also the bandwidth is halved.

There is also the fact that with all sideband transmissions the suppression of the carrier means that heterodyne interference common with closely spaced *am* signals is eliminated. In other words, such transmissions give better separation (smaller bandwidths) and higher signal strengths at the receiver for any given transmitter power. The main limitation is that such transmitters are considerably more complex and costly to construct than simple *am* types, and can be exacting to set up and adjust.

The basic arrangement of a sideband transmitter is shown in Fig. 4.10. Both *af* and *rf* signals are fed into a balancer modulator, the output

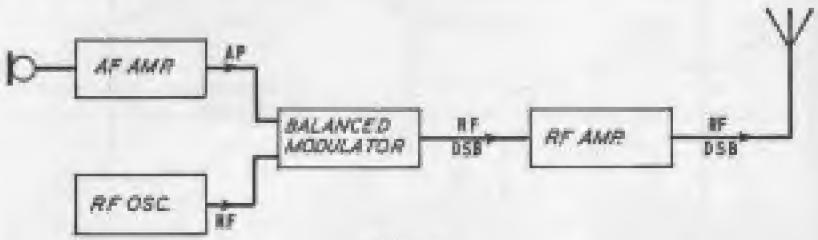


Fig. 4.10

of which is the amplified sidebands of a normal modulator but with the carrier suppressed. If single sideband transmission only is required, then a filter can be interposed to remove the unwanted sideband. The output

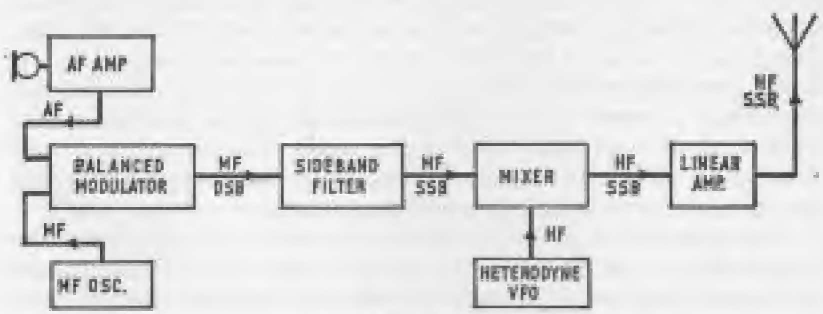


Fig. 4.11

then consists of single sideband *rf* which can be amplified as necessary.

In practice the original *rf* signal is usually crystal controlled, and acts as an *rf* drive (i.e. initial carrier) at a medium frequency. This considerably simplifies the filter requirements since, in general, the lower the centre frequency the easier it is to produce filters with suitable selectivity. The single sideband output is then amplified and heterodyned to the required output frequency, this stage also being made tunable—Fig. 4.11. Any further amplification must then be strictly linear, and a high degree of stability is essential for successful working.

Frequency Modulated Transmission

Some mention should be made of frequency modulated (*fm*) transmission as this is a feature of many modern domestic radios, although little used for amateur radio work. The basic difference between *fm* (frequency modulation) and *am* (amplitude modulation) is that the modulating *af* in the case of *fm* leaves the amplitude of the mixed signal unchanged but produces frequency deviations in the carrier proportional to the instantaneous amplitude of the modulating signal. The difference can be seen by comparing Fig 4.12 with Fig. 4.7.

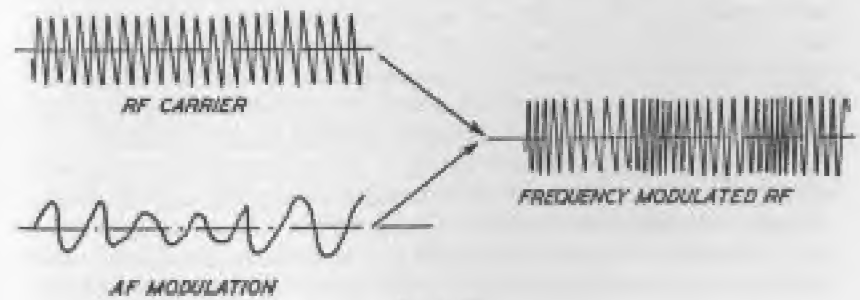


Fig. 4.12

This has certain advantages for 'domestic' radio transmissions, particularly where the bandwidth (represented by the frequency deviations) is not too restricted. For amateur radio work *fm* transmissions are restricted to a maximum bandwidth of less than 2·5 kHz. Such narrow band *fm* transmissions have the advantage that they are less likely to interfere with local television transmissions than *am* or sideband

transmissions, but performance is otherwise generally inferior for amateur work, for the reason already explained in Chapter 1.

Choice of Transmitter

Transmitters can vary widely in coverage and scope. Many transmitters offer *cw* (telegraphy) and *am* (telephony) only, but may be extended to sideband working by the addition of an adaptor. This will not necessarily give satisfactory working, for a s.s.b transmitter is usually designed on somewhat different principles and adaptation of an *am* transmitter necessarily involves compromises, e.g. the modulation may not be applied at an optimum stage.

Similarly, although transmitters may be designed for multi-band working, there are distinct differences in the optimum requirements for *hf* and *vhf* working (as well as power level differences involved). The use of separate transmitters for covering these two ranges is thus usually a better proposition. Much, of course, depends on the type and scope of working aimed at—and how deeply the individual wishes to get involved as an amateur radio station operator. Also power requirements have to be kept in mind. Distance working on the *hf* bands, which tend to be crowded anyway, may require going to the maximum power levels permitted, for maximum scope and satisfaction. On the other hand, many enthusiasts are content to limit their activities to operation on just one or two bands only. And beginners, because of the simpler licence requirements, may well decide to concentrate on telephony, and the associated *vhf* channels available for Sound Licence B holders.

Their initial equipment can therefore be purchased, or constructed accordingly. The more ambitious beginner, however, will be better advised to regard his transmitter in terms of 'black boxes' or individual units, the scope and coverage of which can be extended by additions and modifications, as experience—and confidence—in amateur working is gained.

The form of Amateur Transmitters

The size and physical form of transmitters has changed considerably over the years. Early transmitters were commonly constructed in the form of separate units, mounted on racks or tables, occupying perhaps nearly a whole wall of a room. Unit construction is still widely favoured for valve transmitters, and particularly those for high power working or

further development and experimental work, since additions and/or modifications are more readily tackled.

There is, however, an increasing tendency to produce complete transmitters as a single 'packaged' unit of moderate cabinet or case size. Miniaturization has further been promoted by the application of transistor circuits replacing valve circuits, and even complete transmitter circuits. Originally the application of transistors to transmitter circuits was strictly limited because of the lower power levels of such devices. This need no longer apply, although where high powers are required, valve circuits remain the usual choice (and in some cases the only choice).

With unit construction, of course, there is also the possibility of using 'mixed' construction, i.e. some units with transistor circuits and others based on valve circuits.

Still further miniaturization is possible in modern designs by using integrated circuits, particularly as these have become more widely available during recent years at relatively low cost. Such elements can, to a large extent, simplify home construction, as well as being attractive for professional constructions.

The maximum power permitted for amateur transmitters is 150 watts input for *am* transmissions (*see also* Appendix I). All-transistor transmitters are generally only directly competitive as regards performance in the bands where lower power limits are set, e.g. 10 watts for the 1·8 MHz band; 50 watts for the 70 MHz band; and possibly single sideband transmissions on other frequencies (directly compared with *am* transmissions).

Even greater compactness is realized in certain modern designs by combining transmitter and receiver in one cabinet. Besides reducing the station equipment to a single table-top item this can have the advantage that certain circuits can be common to either the transmitter or receiver. Again this is particularly adaptable to single sideband transmissions where the circuits involved are inherently more complex than *am* types.

Mobile Stations

The general reduction in the bulk and weight of modern transistor transmitters and tranceivers has made the mobile station both a practical and attractive proposition, e.g. for mounting in a car. Problems may be involved in providing efficient protection against interference

from the ignition circuit of the car engine and the power of the transmitter may necessarily be more restricted than could be used with a 'home' station, since the basic source of power supply is usually the car battery. Also an additional Sound Mobile licence is required, which is available only to holders of Sound A or Sound B licences (with the same frequency restrictions applying in the case of the Blicence).

Mobile stations commonly operate on a power of 10 watts or less, and almost invariably on telephony. Average range is of the order of ten to twenty miles, although very much longer distances can be covered under favourable circumstances.

Operation on *vhf* is preferable to *hf*, as apart from other technical considerations this simplifies the aerial requirements. Mobile aerials, for example, must not exceed 14 ft. in height above the ground; and in practice a whip aerial fitted to a car cannot exceed about 7 or 8 ft. in length. This, or shorter, lengths, can be quite adequate for efficient *vhf* transmission, although the favoured form of *vhf* aerial is usually an omnidirectional 'loop' aerial, which is basically a dipole bent in the form of a circle. For *vhf* working this loop need not be larger than about 12 in. diameter to obtain a suitable resonant length (*see* Chapter 8).

Frequency Checking

It is obligatory that a licence holder be able to verify that his transmissions are within the authorized frequency band(s); and to use a satisfactory method of frequency control. In effect, this means that a crystal reference source is needed to comply with these requirements, so that (in the words of the Ministry of Posts and Telecommunications):

(*a*) with a crystal-controlled transmitter an absorption 'device' of suitable frequency range and accuracy is necessary to check that the desired harmonic of the crystal frequency is selected.

(*b*) with a transmitter that is not crystal-controlled a wavemeter based on a crystal oscillator is necessary.

The Ministry of Posts and Telecommunications offer the following notes for general guidance:

(*a*) *Frequency measuring equipment* should be of sufficient accuracy to verify that emissions are within the authorized frequency bands. For example, operation in the centre of the 21·0–21·45 MHz band would

require frequency measurement to an accuracy of $\pm$ 1·0 per cent to ensure that emissions were within band, whereas operation within, say, 10 kHz of band edge would require measurement to an accuracy of $\pm$ 0·05 per cent. When determining the proximity of an emission to band-edge, the bandspread due to modulation, on the appropriate side of the carrier, needs to be added to the frequency tolerance of the carrier.

(*b*) *Heterodyne wavemeters and crystal calibrators.* When used in conjunction with a general coverage receiver, a 100 kHz crystal is usually adequate for checking frequencies up to 4 kHz. For higher frequencies the spacing between 100 kHz marker points is too small for accuracy, and a crystal of 500 kHz, or preferably 1 MHz, should be used in addition. If the receiver covers only the Amateur frequency bands the bandspread scale will usually allow a 100 kHz crystal to be used with sufficient accuracy throughout the *hf* bands.

(*c*) *Absorption wavemeters and similar devices.* The scale length and accuracy should be suitable for measurements of the required accuracy to be made, and the frequency coverage should extend up to the second, and preferably the third, harmonic of the radiated frequency so that the presence of unwanted frequencies may be detected. For *vhf* and *uhf* transmitters, probably the best technique is to measure the frequency of the fundamental oscillator as accurately as possible and to use an absorption device to confirm that the wanted harmonic has been selected. When a *vhf* or *uhf* converter is used in conjunction with an *hf* receiver and the calibration of the main receiver can be checked with sufficient accuracy, this will provide a means of frequency measurement, but it is also advisable to use an absorption wavemeter to check the measurement and to confirm that no unwanted radiations are present.

CHAPTER 5

TRANSMITTERS IN MORE DETAIL

This chapter will be concerned with describing the transmitter circuit requirements, and solutions, in more detail. Since the transmitter can be broken down into a series of interconnected units (whether physically separated or not), as outlined in the previous chapter, it is most convenient to consider the design and characteristics of such units under separate headings.

Oscillator (Master Oscillator)

A primary requirement of an oscillator circuit is that it must be stable, and also unaffected by any external circuits. The former requirement is primarily dependent on the design of the oscillator circuit itself.

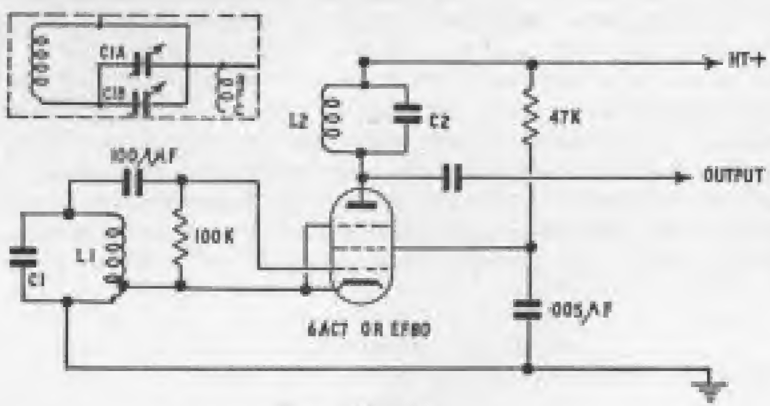


Fig. 5.1

The latter can be met by suitable screening. Mounting and wiring of critical components must also be rigid enough so that mechanical vibrations cannot also be a source of instability.

A basic valve oscillator circuit is shown in Fig. 5.1. L_1 and C_1 form the tuned circuit, the alternating voltage developed across which is fed

to the grid of the valve via C_3. The energy to maintain this alternating voltage of oscillation is derived from the alternating current flowing through the cathode, fed to a tapping point on L_1.

Output is developed in a second tuned circuit L_2 and C_2, driven by the valve. This can be tuned to the same frequency as L_1–C_1, although it will be more advantageous to tune to twice this frequency. This will render the grid circuit largely unaffected by the anode circuit, so that stability is much higher. It is also rather more convenient to tap the capacitance instead of the coil, leading basically to the modification shown in the box in Fig. 5.1. This is known as the Clapp oscillator, the lowest frequency being set by C_1A and the tuned circuit then adjusted over the tuning range provided by C_1B. A radio frequency choke (RFC) is also needed between the cathode and earth to provide a necessary *dc* connection, but offering very high effective resistance to *rf* current.

A practical form of this simple type of variable frequency oscillator (*vfo*) is shown in Fig. 5.2, with typical component values given in Table

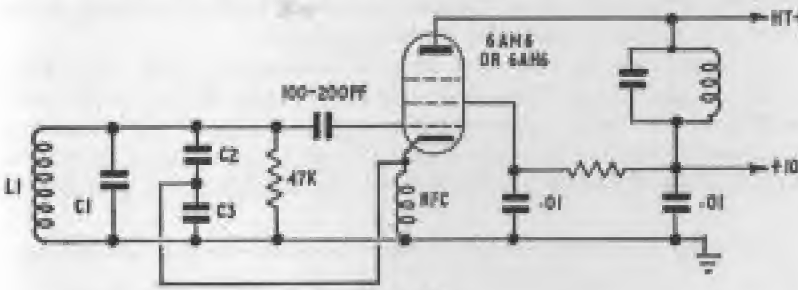


Fig. 5.2

5. The anode circuit L_2–C_2 is tuned to twice the oscillator frequency and the output can be taken from this by capacity coupling, or inductive coupling (L_2 in this case being one coil of the coupling transformer). Frequency stability is largely dependent on the performance of capacitors C_2 and C_4, which must be of high stability type with suitable temperature coefficients.

Better stability can be provided by various other designs, two of the best known being the Franklin oscillator (Fig. 5.3) and the cathode coupled oscillator (Fig. 5.4). Both are shown based on double triode

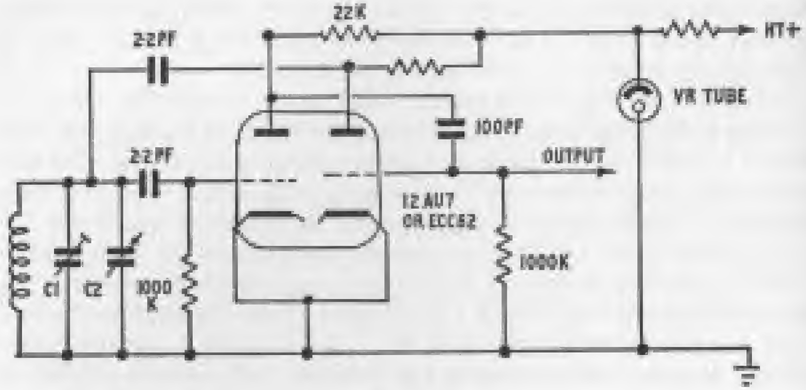


Fig. 5-3

valves, although an extension of the Franklin circuit is also used with two pentode valves. A feature of these circuits is the voltage regulator included. Numerous other designs have also been developed, some specifically suited to particular band frequencies.

Transistor circuits can also provide satisfactory *vfo*'s with high stability—often better than valve circuits because of the lower heat generation. The main requirement is to use high quality *hf* transistors in a properly stabilized circuit. A wide variety of such circuits have been published and are readily available for home constructors, e.g. from the

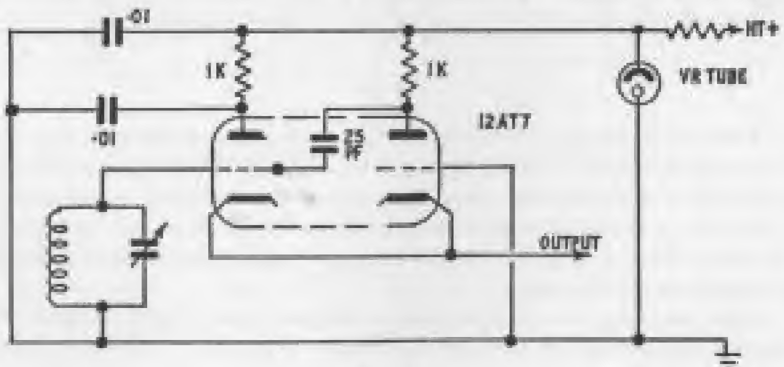


Fig. 5-4

transistor manufacturers and journals dealing with amateur radio subjects.

Crystal Oscillators

A direct method of obtaining stability in an oscillator circuit is to replace the tuned circuit L1–C1 with a piezoelectric element or *crystal* having the required resonant frequency—Fig. 5.5. The stability of the

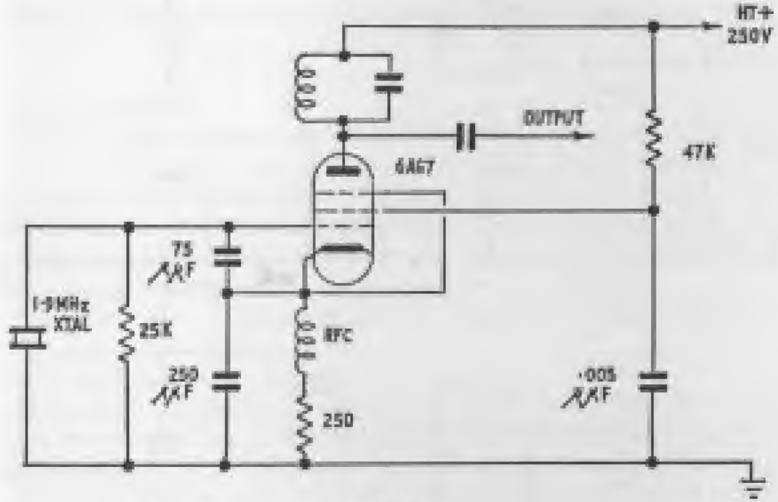


Fig. 5-5

circuit will then be as good as that of the crystal, although this in turn will depend on the mode in which the crystal is operated. In series mode the stability is usually higher than in parallel mode, although the *rf* output is substantially reduced. There are also other objections to series mode working, so that parallel mode circuits are more widely employed. Three of these basic circuits are shown in Fig. 5.6.

The higher the frequency, the more crystal control becomes attractive as a means of oscillator stabilization. Unfortunately this does not conform to typical crystal characteristics in that the higher the resonant frequency the more difficult it is to produce satisfactory crystal forms and crystal performance. Temperature effects may also

become exaggerated, particularly when allied to transistor oscillator circuits.

To a large extent this problem is being overcome by the availability of better and more stable crystals particularly developed for high frequency use. Alternatively some circuit designers prefer to use a crystal with a lower resonant frequency as likely to be more stable (or

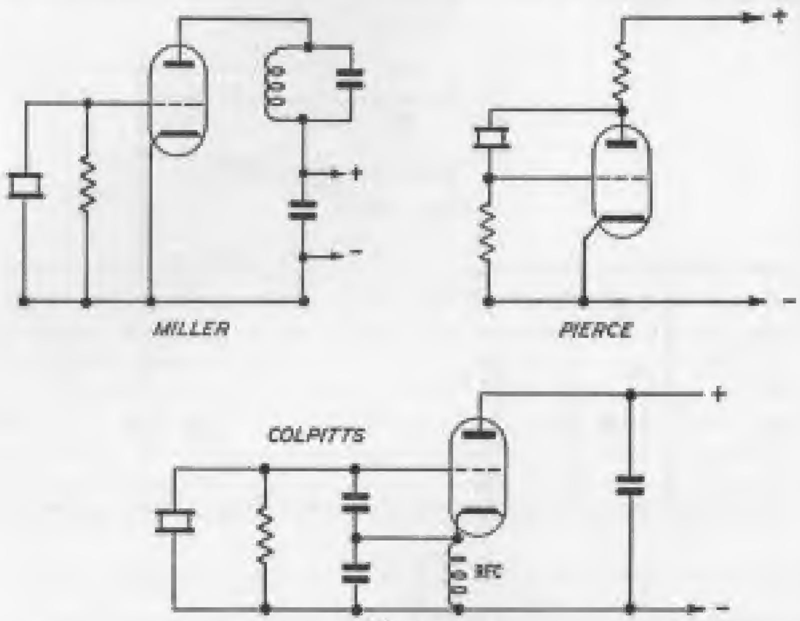


Fig. 5.6

more readily available) and then arrive at the required high frequency by applying multiplication to the oscillator itself. Such a circuit is known as an *overtone* type, the oscillator frequency then being a harmonic (multiple) of the fundamental frequency of the crystal used.

Such treatment also can be used to overcome one limitation of crystal control in that it provides stability around one 'spot' frequency. A crystal oscillator is thus, basically, a single frequency oscillator. It can, however, be 'tuned' over a small range by adding reactance in series to 'pull' the crystal to one side or other of its fundamental frequency. This,

together with multiplication as necessary, can be used to produce a variable crystal oscillator.

Again a large variety of crystal oscillator circuits have been published, and are readily available. Some, however, may prove temperamental or unsatisfactory in use. Probably the best advice for the amateur designer/constructor is to adopt an oscillator circuit specifically recommended, or published, by the crystal manufacturer, unless he is prepared to undertake a considerable amount of experimental work in 'proving' (or otherwise) the performance of individual published designs.

Voltage Regulators

High tension voltage regulation in the case of valve circuits can readily be provided by a special type of valve, commonly referred to as a VR-tube. Suitably connected, and operated within its design current range, this can provide stabilization of the high tension supply.

In the case of transistor circuits working at very much lower voltages, Zener diodes can be used for similar purposes.

This particular subject is covered in Chapter 7, Power Supplies.

Power Amplifiers (rf Amplifiers)

In general oscillators are designed to work at relatively low power levels in order to preserve good stability. Since the oscillator produces the basic signal, it is followed by one or more power amplifiers to increase the signal output applied to the aerial at the required power level. Such amplifiers are generally described by their mode or *class* of working.

Fig. 5.7 shows a typical power amplifier circuit, based around a pentode or tetrode valve. The three methods of operating the valve are then as follows (*see also* Fig. 5.8):

Class A. The grid of the valve is negatively biased to about one half of the cut-off point. The 'standing' anode current will then be moderately high and a sine wave input voltage will produce a corresponding sine wave anode current, providing the *rf* amplitude is not excessive, as otherwise this would result in 'clipping' of the bottom of the anode current waves.

Class B. Here the bias is increased to the cut-off point (or very nearly

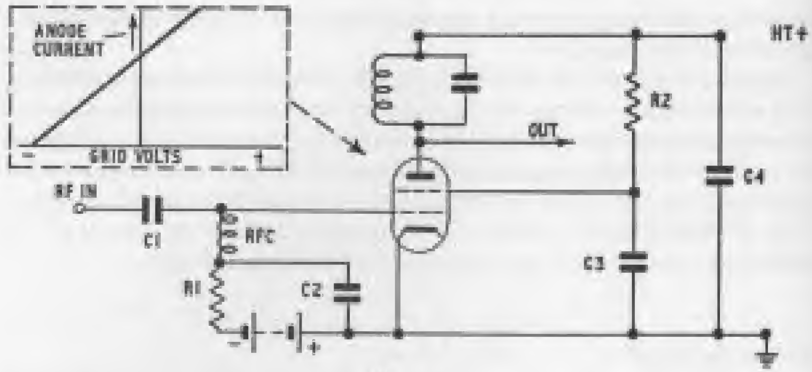


Fig. 5-7

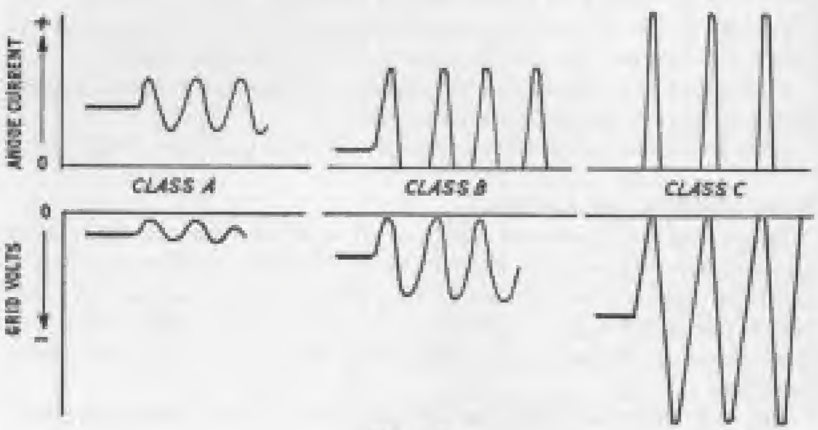


Fig. 5-8

so). The effect of this is that when *rf* input is applied only the top halves of the corresponding sine wave appear as anode current, so that anode current only flows for one half of every cycle. Higher peaks of anode current can, however, be obtained for the same *average* anode current. As a consequence, more *rf* output power can be obtained for a given power consumption by the valve, at the expense of higher *rf input* power required.

Class C. Here the bias is increased to two times or more of the cut-off

point, producing even more sharply peaked anode current characteristics with *rf* input, each peak occupying less than half a cycle. Thus even more *rf* output power can be obtained for a given input power to the valve (represented by the *ht* consumption) but again at the expense of higher *rf* input power required.

As a rough comparison, Class B operation gives about twice the efficiency of Class A operation (i.e. twice the *rf* output power for a given input power)—*see also* Table 6. Class C operation can be expected to give about 10 per cent more efficiency than Class B. Either of the latter two may be chosen—Class C for maximum efficiency and thus maximum *rf* output; or Class B because it has the additional virtue that the output can be made directly proportional to the *rf* input. A number of other important factors must, however, be considered in the final design of the circuit, notably the method of providing the grid bias, control of the anode current, feedback and neutralization, and the method of inter-stage coupling.

Where the power output required is more than can be given by one valve, instead of using two or more stages of amplification, two or more valves can be connected together in parallel, with the similar elements in all the valves connected together. *Parallel operation* will give an output in proportion to the number of valves used for the same high tension voltage, but the input power will also increase in proportion to the number of valves.

An alternative method is to employ two valves in *push-pull* configuration. Here the circuit is split, mirror-image fashion, so that the voltages and currents of one valve are out of phase with those of the other. As the anode current in one valve is rising, that of the other is falling, giving in effect a push-pull operation—Fig. 5-9. The advantage of such a system is that less distortion is produced, compared with parallel operation, for the same power output. The main disadvantage is that twice the *ht* voltage is required, which can severely limit the application of push-pull amplifiers for valve transmitters.

The Anode Circuit

The anode circuit comprises a combination of inductance (L) and capacitance (C), forming a tuned circuit (often referred to as the tank circuit). A study of Fig. 5.8 will show that if off tuned with regard to the *rf* input the anode current will be relatively high; but if tuned to

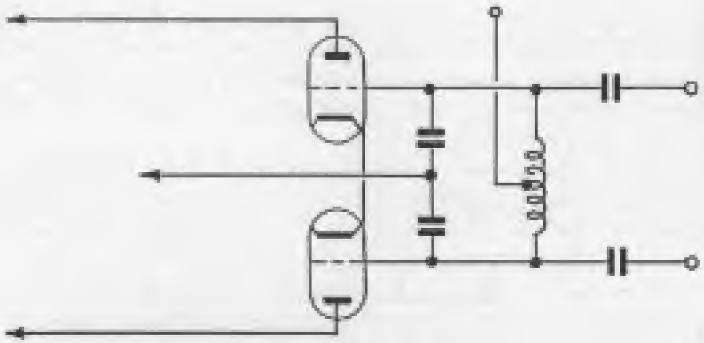


Fig. 5.9

resonance the average anode current will be very low. This forms a useful method of tuning the anode circuit, i.e. adjusting for minimum anode current. This does not, however, give any indication of the *rf* voltages which may be present. These can be excessively high in the absence of any anode load, pulling the valve into a condition where the screen current is excessive. Once a load is coupled to the anode circuit energy will be drawn from the tuned circuit, reducing both the *rf* voltage and the *rf* current. It also follows that this load can modify the tuning of the tuned circuit, unless it is purely resistive.

The two principal points which emerge from this are:

1. For initial tuning and setting up of a power amplifier, with no connected load, the *ht* voltage should be reduced in order to eliminate the possibility of excessively high *rf* voltages being developed.

2. Some retuning of the anode circuit may be necessary after coupling to an external load (e.g. the aerial, or a following amplifier stage), to compensate for any inductance of capacitance introduced by the coupled load.

Correct loading is also important as this controls the quality of the *rf* output radiated by the aerial. This requires a suitable compromise between energy efficiency and damping, generally related to the quality factor or Q of the circuit. This, basically, is the ratio of the energy stored to that dissipated in each cycle of operation. A high Q implies high efficiency and low damping; a low Q, low efficiency and high

damping. The necessary compromise aims at providing good efficiency with enough damping to avoid a distorted *rf* output, introducing a series of harmonic frequencies which could cause interference on these equivalent bands. This places a premium on the values and quality of the inductance (coil) and capacitor employed in the anode circuit, and the selection (or adjustment) of the aerial load and its coupling.

The type of coupling preferred is of the kind where the tuned circuit is isolated from the *ht* by a capacitor, as shown in Fig. 5.10. A *dc* path

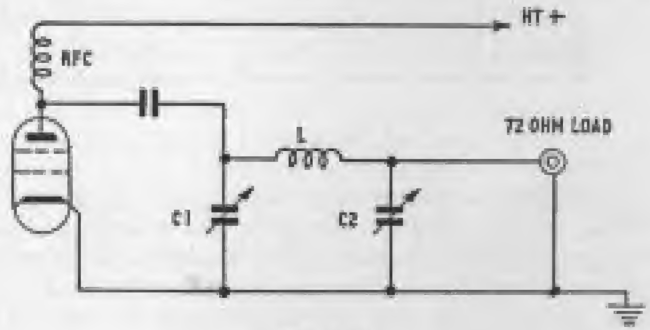


Fig. 5.10

for *ht* is provided by a RFC. The aerial output lead can then be tapped into either the coil or the capacitor. The latter is more convenient since the tapping point can be between two capacitors, each of which is adjustable not only to adjust tuning but also the effective tapping point.

This is shown in final form in Fig. 5.11, known as a *pi-network* circuit. This is generally regarded as the best type of circuit for harmonic suppression, particularly for use in the 3·5, 7, 14, 21 and 28 MHz bands.

Modulation

The most common form of amplitude modulation is *anode modulation* where the modulating signal is applied in the anode circuit of the power amplifier, via transformer coupling—Fig. 5.12. This does, however, demand the use of relatively high *af* power input, such as that given by a Class B audio amplifier. For 100 per cent modulation the average

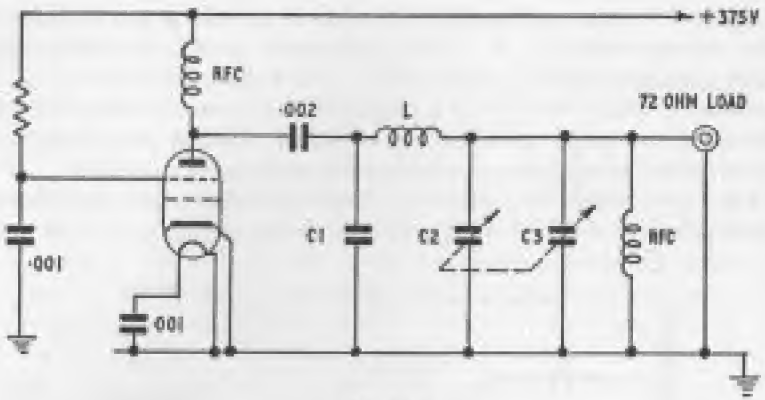


Fig. 5.11

power output of the modulated stage must increase 50 per cent so that the modulator must supply to the modulated *rf* stage audio power equal to 50 per cent of the *dc* anode power. Something less than 100 per cent modulation may, however, be acceptable for telephony, but over-modulation (over 100 per cent modulation) is to be avoided as this introduces severe distortion.

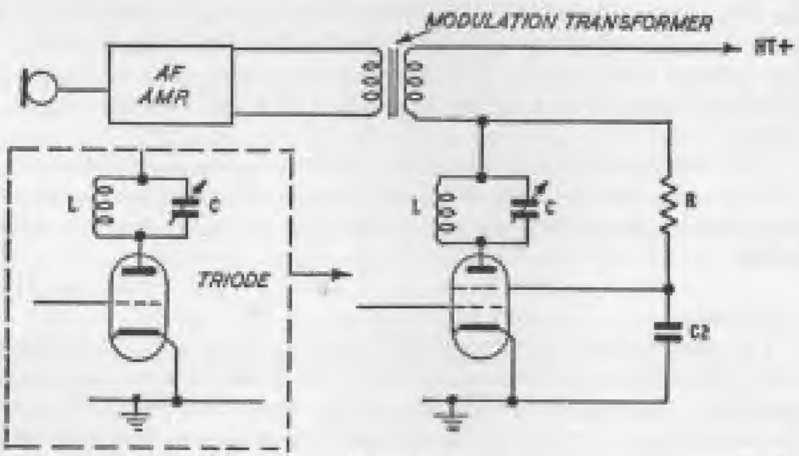


Fig. 5.12

Distortion is also caused by lack of *linearity*. Within the limit of 100 per cent modulation the amplitude of the carrier should faithfully follow the amplitude variations of the modulating *af* signal applied to it. If the modulated *rf* amplifier has non-linear characteristics, then the waveform envelope will be distorted. To maintain linear characteristics it is essential that the *rf* power output must vary as the square of the anode voltage, implying Class C operation. Linearity then depends on having sufficient grid excitation and proper bias, in conjunction with suitable component values. In practice this favours the use of a fixed source of grid bias equivalent to about the cut-off point (i.e. Class B point), supplemented by further grid-leak bias to shift the amplifier into Class C operation.

A typical modulator incorporates an *af* amplifier with microphone input and as many stages of amplification as necessary to achieve the required output. The output terminates in a matched modulation transformer for direct connection to the *rf* amplifier; or as a terminal output for connecting to a suitable modulation transformer. In the latter case it is necessary to select the transformer for the correct impedance match. The load resistance presented to the modulator by the *rf* amplifier valve can be calculated as:

$$\text{resistance (ohms)} = \frac{\textit{ht}\text{ voltage}}{\textit{ht}\text{ current (amps)}}$$

The turns ratio can then be determined accordingly so that when this load resistance is effective across the secondary, the primary resistance has the recommended anode-to-anode value recommended for the *af* output valve(s) involved.

Alternative systems of modulation are *grid-bias modulation*, *screen-grid modulation* and *cathode modulation*. With grid-bias modulation the *af* is introduced in the grid-bias supply, the audio voltage thus varying the grid bias and with it the power output of the *rf* stage. This is far less efficient than anode modulation, but less power is required from the *af* amplifier and the circuit can often be simplified. It may, however, place limitations on the working of the *rf* amplifier, e.g. grid-leak bias working is no longer satisfactory.

Screen-grid modulation again places less demand on the *af* amplifier. Characteristics are generally similar to grid-bias modulation, with

linear characteristics maintained up to 100 per cent modulation with suitable valves.

Cathode-modulation offers a compromise between anode-modulation and grid-bias modulation, with an efficiency about mid-way between the two. The *af* input is introduced in the cathode circuit and both the grid bias and anode voltage vary during modulation. The efficiency depends largely on the proportion of grid modulation to anode modulation. The higher the proportion of anode modulation the higher the efficiency which can be realized; and at the same time the higher the audio power required.

Numerous other variations on modulation have been developed and continue to be evolved by amateur experimenters with varying results.

Audio Compressors

As mentioned in the previous chapter, sideband spread is undesirable, as well as being wasteful of power. There is also the point that sharp tuning of a receiver will probably restrict reception to within 3,000 Hz or less on either side of the carrier frequency, so that any sideband transmissions outside this range will not be heard anyway. Narrowing the sideband width by restricting the range of *af* frequencies superimposed on the carrier will therefore be advantageous, both from an operating point of view and in order to concentrate the power available into a narrower bandwidth containing all the useful audio frequencies—say 200–300 Hz to 3,000 Hz.

To do this it is only necessary to choose a sufficiently small value for one of the coupling capacitors in the *af* amplifier (preferably at an early stage) to block or suppress the lower frequencies (say under 300 Hz). The unwanted higher frequencies can then be cut off at the modulation transformer stage, by adding a suitable capacitor across one of both windings, further reducing the bandwidth of the *af* signal passed on to the *rf* amplifier valve.

A further refinement which may be added is automatic modulation control, also known as audio compression, although providing a quite different feature to sideband compression. This is really a method of automatically holding the output of the modulator reasonably constant over fairly wide ranges of input. This, for example, can make the performance of the modulator non-critical as regards the distance of the

microphone from the speaker's lips, and can also be adjusted to eliminate any possibility of over modulation.

A simple method of achieving this automatic level control is to tap a small proportion of the modulator output, rectify it and use the negative *dc* obtained to control the gain of an early stage of the amplifier, similar to the automatic gain control principle used in receivers.

Another method of preventing over modulation is by speech clipping. This involves 'clipping' the positive and negative peaks produced in the *af* circuit, so that the peak amplitude can never exceed the carrier amplitude (which would result in over modulation). At the same time this abrupt cutting will produce 'spatter', which will need removing at the output stage by a suitable filter or filters. The same filters can also provide the degree of audio compression required.

Power Supplies

Power supplies form a virtually complete subject on their own as far as valve transmitters are concerned. The demand may be as high as 1,500 volts *ht* at up to 300 milliamps; much lower bias voltages; and still lower voltage heater supplies. The requirements may also be for particular stages of a transmitter to be supplied separately. The components involved tend to be bulky, heavy, and expensive. Also even the more moderate *ht* supplies of, say, 350 volts present a very real hazard which can only be countered by 'safe' design and disciplined handling technique.

Although part of any (valve) transmitter set-up, the technical and practical aspects involved are dealt with in a further chapter, as worthy of separate study.

Drivers

The term *driver* is often used in describing radio circuits (both transmitters and receivers). Strictly speaking a *driver* is the power developed in the anode of one valve (or equivalent circuit in the case of a transistor) which is fed to and powers or 'drives' the following stage. Thus any preceding stage in a circuit is really the driver for the next stage. The 'driver' is often considered as an entity because the driving source should always have good regulation. In some circuit designs, e.g. particularly transistor circuits, a complete stage may be designed and operated as a driver.

Exciters

An exciter is basically a source of excitation for a following circuit. Thus a microphone is an exciter for the following *rf* amplifier stage, for example. However, the description 'exciter' is specifically given to multiplier/amplifier units, used as one of the 'black boxes' in unit transmitter assembly which provides *rf* output on various, or required bands.

Neutralization

Neutralization is an important feature in a valve circuit where the valve anode-to-grid capacitance may be high enough to cause unwanted interaction. This is 'neutralized' by a modification of the circuit to include a neutralizing circuit. A typical circuit of this type uses a centre-tapped anode coil, tuned by a split-stator capacitor. The voltage at the upper end of the anode coil is fed back through a *neutralizing* capacitor, the value of which is selected (or normally adjusted) to cancel out the anode-grid capacitance.

There are also other types of neutralizing circuits, providing the same effect. The main thing is that when a neutralizing circuit is included, the neutralizing capacitor provides a means of controlling the anode-grid capacitance developed by the valve. This can be necessary with certain types of valves, particularly for high frequency working.

TV Interference

The adoption of a pi-network tank circuit does not automatically ensure that no harmonics are radiated which may show up, particularly as interference on near-by television receivers, when a transmitter is being worked on the various amateur bands. The problem of TV interference can be a considerable one, not only because of the vast number of TV sets likely to be in operation in any locality during leisure hours, but also because of the subjective reaction to TV interference. Visual interference is much more a subject for complaint than audio interference!

Harmonic radiations are the most common cause of TV interference. Logically, therefore, the aim must be to keep any harmonic generation low by good circuit design (avoiding those which generate badly distorted waveforms, for example), efficient decoupling and any other

treatment found necessary. Again this cannot be relied upon completely to eliminate harmonics and so the next step is to take all possible steps to maintain the harmonics *inside* the transmitter. This, basically, is a matter of effective screening, and the use of filters where necessary. Leads emerging from the cabinet, for example, can benefit from filtering, particularly in the transmission line leading to the aerial system. For transmitting in the amateur bands from 1·8 to 21 MHz, for example, a low pass filter can allow effective operation on all these bands but stop any higher frequencies present being radiated, which should go a long way to minimizing local TV interference. Some operators may prefer to go even further and fit bandpass filters which pass only the frequencies in the band on which they are operating, suppressing all others which may be present in the radiation.

Table 5. Typical Component Values for a Variable Frequency Oscillator

(*See* circuit, Fig. 5.2)

Tuning range MHz	*L1 H*	*C1 pF*	*C2 pF*	*C4 pF*
1·75 – 1·88	3·0	15 – 300	4000	4000
3·5 – 3·75	1·3	10 – 250	2500	2500
3·5 – 4·0	1·5	15 – 300	2000	2000
5·0 – 5·5	0·9	10 – 230	2000	2000
6·0 – 6·25	0·5	8 – 150	2500	2500
6·0 – 6·5	0·6	10 – 200	2000	2000
7·0 – 7·2	0·5	8 – 150	2000	2000
8·0 – 8·22	0·35	6 – 100	2000	2000
8·33 – 8·66	0·35	6 – 100	2000	2000

Table 6. Classes of Amplifiers

Class	*Bias*	*Characteristics*
A	Low.	Never driven positive with respect to cathode. Never driven to cut-off point low power output. High power amplification ratio. Output wave form is faithful. Reproduction of input wave form. Best suited for audio amplifiers.
B	Medium (to set low anode current).	Entire linear portion of valve used. Medium power output. Medium efficiency. Moderate power-amplification ratio. Can be used as linear amplifiers.
AB	To operate as Class A at low signal voltages, and Class B at higher signal voltages.	Low distortion at moderate signal levels. High anode efficiency at high signal levels. Suitable for audio amplifiers.
AB_1	As AB.	As AB, but draws no grid current and thus draws no power from the driving source.
AB_2	As AB.	As AB, but draws grid current at higher signal levels.
C	Well past cut-off.	Badly distorted output waveform (thus limited to *rf* amplifiers) high anode efficiency. High power output.

Table 7. Power Amplifier — Typical Operating Conditions

Valve type	*Anode*		*Screen*		*Bias volts*	*rf load impedance ohms*
	volts	mA	*volts*	mA		
6146	500	40	150	2	− 22	470
807	500	50	200	1·6	− 15	280
5B/254M	500	50	200	1·6	− 15	280
6146B	600	24 − 125	200	5 − 7·9	− 47	2800
	750	24 − 125	200	3·9 − 6·3	− 48	3600
TT21/22	800	40 − 122	300	0·5 − 11	− 38	4500
	1000	35 − 116	300	0·3 − 10	− 40	6500
	1250	28 − 136	300	0·1 − 8	− 45	6500
4CX250B	1000	83 − 250	350	6 − 30	− 55	1650
	1500	83 − 250	350	9·5 − 30	− 55	3000

Table 8. Typical Pi-Filter Component Values*
(*See* circuit, Fig. 5.11)

ht *anode current*	*Frequency MHz*	*L* *μH*	*C1* *μμF*	*C2* *μμF*
4	1·8	17·2	560	2920
	3·5	8·6	280	1460
	7	4·3	140	730
	14	2·1	70	365
	21			
	28			
6	1·8	24·4	400	2560
	3·5	12·2	200	1280
	7	6·1	100	640
	14	3·1	50	320
	21	2·0	33	215
	28	1·5	25	160
8	1·8	31·2	300	2240
	3·5	15·6	150	1120
	7	7·8	75	560
	14	3·9	37·5	280
	21	2·6	25	180
	28	2·0	17·5	140
10	1·8	22·0	240	2040
	3·5	11·0	120	1020
	7	5·5	60	510
	14	4·75	30	255
	21	3·2	20	170
	28	2·5	15	130

* Following a typical beam tetrode valve and feeding into a 72 ohm load

CHAPTER 6

RECEIVER PRINCIPLES AND PRACTICE

THE two basic elements in any radio receiver are a tuned circuit and a detector. The former provides selection of (i.e. tuning in to) the desired radio signal, which is then fed as an *rf* input to the detector circuit. This circuit works effectively as a rectifier, converting the modulated *rf* wave into a varying *dc* current, the amplitude of which will vary at the same rate as the modulation frequency. This is at audio frequency and thus the detector output signal can be heard by feeding to a suitable device, e.g. headphones.

Normally the incoming signals will be weak, and the output correspondingly weak. In order to produce sufficient power for conversion to audible output, amplification of the signal is required. This can be applied to the incoming signal, e.g. by interposing an *rf* amplifier between the tuned circuit and the detector; or to the output or demodulated signal from the detector—using an *af* amplifier; or to both input and output signals.

The simplest form of detector circuit is based around a diode rectifier —Fig. 6.1. There are also numerous other approaches using a triode or pentode valve, with the possibility of improving the performance. Thus by providing controlled *rf* feedback in a triode or pentode circuit the incoming signal can be subject to amplification (increasing sensitivity) and the effective Q of the circuit improved by regeneration (increasing selectivity)—Fig. 6.2. Such circuits are known as *regenerative detectors*.

The limit to which amplification can be produced is set by the point at which oscillation starts. This can be delayed by introducing a low frequency alternating voltage (quench frequency) in the detector circuit in such a manner as to vary the operating point of the detector. This type of circuit is known as a *superregenerative detector*.

The combination of *rf* amplifier-detector-*af* amplifier is known as a *tuned radio frequency* (TRF) receiver and represents the simplest type of design for amateur radio listening. Its performance, however, is distinctly limited since both its selectivity and sensitivity is relatively

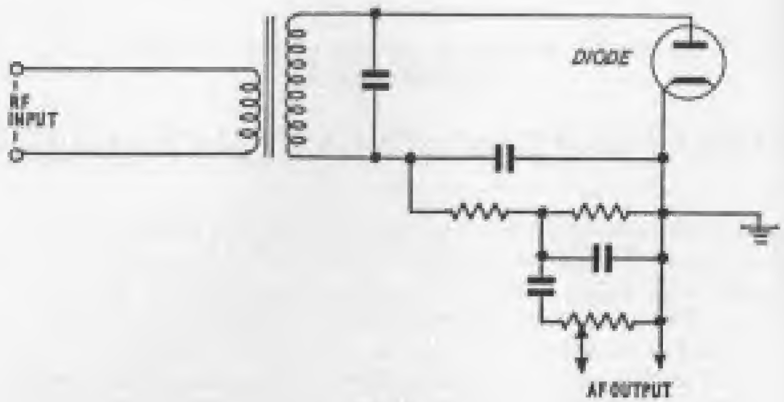


Fig. 6.1

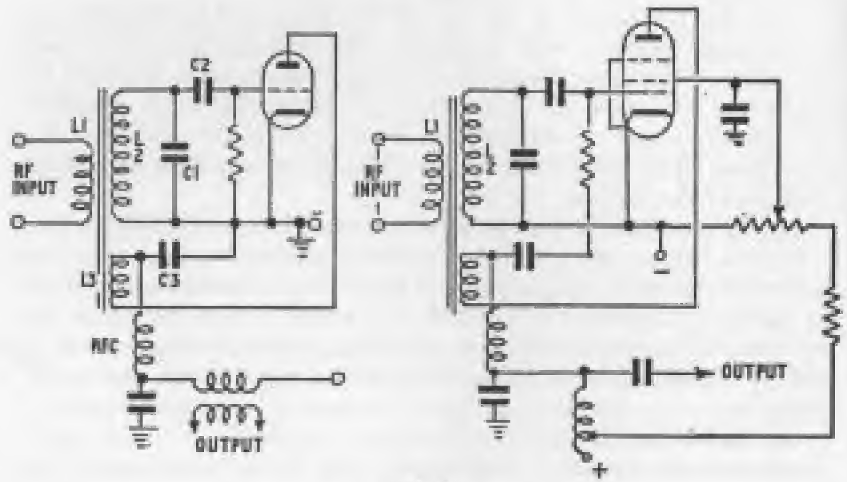


Fig. 6.2

poor, and selectivity deteriorates badly with increasing *rf* frequency. It is thus only likely to give satisfactory results on the lower frequency bands, e.g. 1·8 and 3·5 MHz using a diode detector. Some improvement can be realized using a regenerative detector, and a superregen receiver is even better for higher frequencies (this type, in fact, works

best on very high frequencies). The superregen detector, however, is suitable only for use with modulated signals. The main advantage of a TRF receiver is that it is relatively easy to construct and simple to set up.

The *superheterodyne receiver* offers a considerable improvement in performance, at the expense of a more complicated circuit network—*see* Fig. 6.3. The incoming *rf* signal is fed to a *mixer* or *converter*, this section

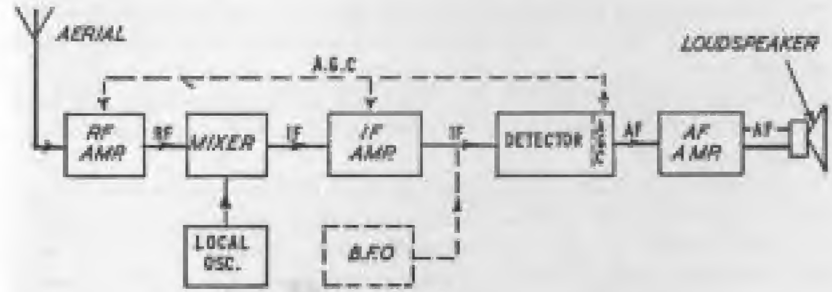


Fig. 6.3

also being fed by a separate high frequency signal from a *local oscillator*. The mixer combines these two signals to produce a *beat frequency* or *intermediate frequency* equal to the difference between the two frequencies. The common value of intermediate frequency (*if*) chosen is about 470 KHz, and remains the same regardless of the frequency of the *rf* signal. In other words the local oscillator tunes *with* the aerial tuning circuit, so that the high frequency signal it supplies always differs from the *rf* by the predetermined (fixed) value of *if* chosen. The intermediate frequency supplied as output from the mixer is then amplified before being fed to the detector, the output from this stage being subject to *af* amplication as necessary. It is thus the 'front end' of the complete circuit which is markedly changed.

The advantage of this type of circuit is that frequency conversion permits *rf* amplification at a relatively low frequency (the *if* frequency), thus providing high selectivity, and selectivity which remains constant regardless of the *rf* signal frequency (the same *if* is being amplified). It also lends itself to further improvement in selectivity by sharpening the peak of the selectivity curve and thus narrowing the actual bandwidth

received. It is here, largely, that superhet communications receivers differ in design from domestic broadcast type superhet receivers.

The main limitation of the superhet circuit is its susceptibility to *image* reception. Suppose the intermediate frequency employed in the circuit is f (fixed) and the radio frequency of interest (variable) is F. The mixer can be regarded as a sort of 'first detector' and so all the following circuits are designed to respond to an input at a frequency of f, the mixer itself always putting out this frequency when it is supplied with an *rf* input of F and a signal from the local oscillator which has a frequency of F+f *or* F−f. Normally the local oscillator frequency used is F+f.

When the set is tuned to F, the mixer thus receives one input at F and one at F+f, from which it extracts the difference (f), regardless of the actual value of F.

Suppose there is also an *rf* signal present with a frequency of F+2f. As far as the mixer is concerned it is now dealing with a second combination of (F+2f)—(F+f) = f, and so this will also appear as an *if* output. In other words, F+2f is an 'image' frequency which will be passed on by the mixer as a beat frequency. The strength of this image, relative to the strength of the true signal required, depends largely on the selectivity of the tuned circuit(s) preceding the mixer, thus placing a premium on the design of such circuits, particularly as the *rf* frequency involved increases. Thus for the same 'sharpness' of tuning, e.g. restricting the tuned bandwidth to less than 2f, the *percentage* difference involved (2f compared with F) decreases in proportion to increasing values of F.

One possible way of overcoming this is to increase the value of the *if* used, as this will spread the image farther away from the true signal required (the image will always be 2f away from the true signal). Unfortunately, this represents exactly the opposite requirement for good *selectivity*, because the lower the *if* the more favourable the percentage difference becomes.

The *double superheterodyne* circuit provides for using a high *if* to produce a high order of image rejection, then changing to a low *if* for high selectivity—Fig. 6.4. Although, in basis, this only involves the addition of a frequency changer, the resulting circuitry is usually considerably more complex than that of a simple superhet and presents additional problems in alignment and stability.

Any of the basic types of sets so far described will receive telephony by demodulation of the modulated *rf* signal put out by a transmitter. They will not, however, receive ordinary telegraphy satisfactorily, since the transmission in this case consists of pulsed carrier wave or *rf* frequencies. In practice, 'pulsing' or interrupting a carrier wave in sending Morse is equivalent to modulation, and some audio frequency content will be

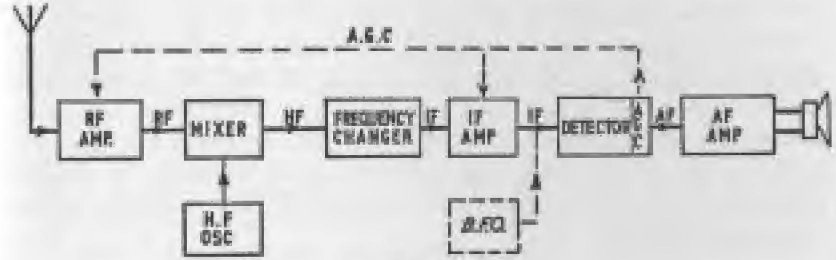


Fig. 6.4

present. Thus code signals can often be heard as a series of somewhat indistinct 'thumps'.

To render them properly audible it is necessary to inject a second *rf* signal into the detector circuit, differing from the signal frequency by a suitable audio frequency, thus producing a beat note which can be heard. The frequency difference chosen is usually 500 to 1,000 Hz, since this range provides the best type of 'note' for listening to.

The principle involved in producing a beat note is similar to that of the superhet mixer stage, although in this case the frequency difference involved is much lower (an audio frequency, not a frequency intermediate between *rf* and *af*). The second radio frequency necessary to produce this beat note can conveniently be supplied by a separate oscillator, known as a beat frequency oscillator, when the complete system is known as *heterodyne* reception. Alternatively, the detector circuit itself can be made to oscillate and provide the necessary second *rf*. In this case it is called an *autodyne detector*.

Similar considerations apply for the reception of suppressed carrier transmissions, where the missing carrier must be inserted into the detector stage in order to realize an intelligible *af* output. To avoid distortion this injected signal must be very stable, so a separate crystal

controlled oscillator is normally employed for this purpose. The design of suppressed carrier receivers also poses a number of other special requirements.

The Homodyne

Another type of receiver which has recently come to the fore is the *homodyne* (also referred to as 'synchrodyne' or 'direct conversion' receiver). In effect this is rather like a superhet receiver utilizing an intermediate frequency of 0 (zero), so that the incoming signal is *directly* converted into *af*. The technicalities invoked are considerably more complex and, in fact, such a receiver type does become extremely complex for *am* reception. It can, however, be very much simplified for receiving *ssb* transmissions and offers considerable scope for experimentation in this field for the more experienced, and technically knowledgeable, amateur.

Tuning

The domestic radio receiver provides for tuning over a relatively wide range of frequencies in each of the available bands. At the same time the tuning has to be fairly 'broad' in order to avoid loss of the *af* content in the modulated signal. This may call for using a bandwidth anything up to 20 KHz (i.e. 10 KHz on either side of the nominal station frequency). In the case of amateur radio working, not only are the effective bandwidths employed much narrower, but the 'passband' widths required are also much smaller. A passband width of 5 KHz is quite adequate for telephony, whilst still retaining good fidelity; and in the case of telegraphy the passband width can be even more restricted.

Tuning is also made easier if the whole of the tuning control range can be restricted to the frequency band of particular interest, e.g. 1·8 MHz, 3·5 MHz, and so on. This will first of all (usually) involve the use of separate tuned circuits which can be selected by switching, or the interchange of coils. Adjustment to any particular position can then be made easier by 'spreading' the tuning scale.

One obvious method is to 'magnify' the movement of the control knob so that a relatively large movement is necessary to produce a small change in adjustment of the variable component in the tuned circuit. The effectiveness of such a mechanical system is more or less

governed by the amount of 'backlash' present in the mechanical movement(s) involved.

The alternative method is to use a bandspreading tuned circuit (*bandspread tuning*). Three such circuits are shown in Fig. 6.5. In the first,

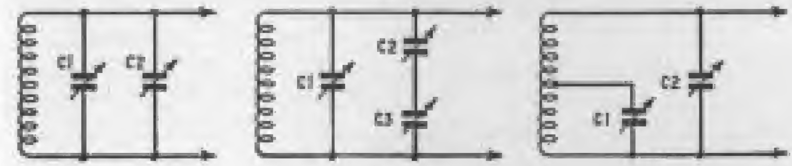


Fig. 6.5

C1 is a variable capacitor of a suitable high value to give a tuning (frequency) range of about 2 : 1, and can be regarded as a coarse tuning control. Another variable capacitor C2 with a much smaller value is connected in parallel, and provides fine tuning control. C1, in effect, is adjusted to *set* the band; when C2 is manipulated to provide bandspread tuning.

The second circuit provides rather more complete bandspreading, but now requires three different controls. But it also offers the advantage of providing different degrees of bandspreading to suit individual bands. This same facility is also provided in the third circuit, reverting to two controls again, plus further variation by altering the tapping point on the coil. The nearer the tapping point to the bottom of the coil the greater the bandspreading, and vice versa.

Converters

Short-wave receivers are designed to cover the 1·8 to 28 MHz bands, or selected bands within this range. To extend the range to *vhf* reception a *converter* can be used. Basically this is a circuit capable of tuning to the *vhf* frequency or frequencies required, yielding an *rf* output signal of the order that the receiver can accept—Fig. 6.6. If the output is tuned to the same frequency as the receiver, all the tuning can be done with the converter. The converter itself may be designed to cover a specific *vhf* band, or a number of *vhf* bands. Ordinary general purpose receivers can be adapted for *vhf* reception in this manner.

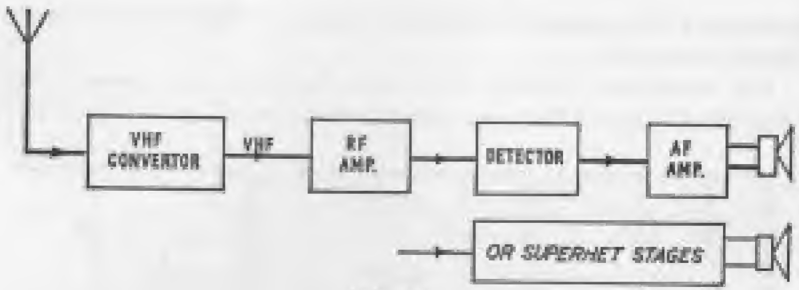


Fig. 6.6

Cross-modulation

Cross-modulation is a form of interference due to a valve being overloaded so that it is working outside the linear range of its characteristics. As a result the valve acts as a modulator, modulating the desired signal with another strong and unwanted signal. In the case of a superhet receiver this can cause *blocking*, since the modulated signal may lie outside the *if* passband at later stages of the receiver. The basic requirements to avoid cross-modulation are, therefore, the employment of valves with good linear characteristics in the *rf* amplifier stage(*s*) and mixer, and avoiding overloading of valves which could push their operating point outside the linear range. The phenomenon is not confined to valves, however. Transistors are also susceptible to this effect, and in general worse than valves in this respect. It should also be noted that the use of automatic gain control (*agc*) can also induce cross-modulation.

'Noise'

A certain amount of circuit noise will be inherent in any receiver. This, basically, governs the *sensitivity* of the set for it is obviously impossible to receive any signals of lower strength than the inherent 'noise' level. However much amplification is applied, the self-noise would mask the signal. Thus sensitivity can be expressed directly in terms of *signal-to-noise ratio*, the higher this ratio the better the selectivity possible.

The problem is not quite as straightforward as this, however. The inherent 'noise' generated by a valve can be considered in terms of an

equivalent resistance in series with the grid of the valve, known as the *equivalent noise resistance* (e.n.r.). This will vary with different types and designs of valves (modern valves are very much improved in this respect), and also with the manner in which the valve is employed, e.g. *see* Table 9. Basically, any mixer valve will be very much noisier than an *rf* amplifier valve. Thus an *rf* amplifier will have a much better signal-to-noise ratio than a mixer.

This emphasizes the importance of an *rf* amplifier stage (or stages) in a superhet circuit for improved sensitivity. The fact that the signal-to-noise ratio is favourable means that quite weak signals can be isolated, and amplified with noiseless gain before being passed on to the noisier mixer stage, making the set much more sensitive than it would be if the original *rf* signals were fed direct to the mixer from the aerial circuit. Also, of course, a higher signal level is present in the mixer, because of preamplification, needing less further amplification at subsequent stages, but the gain must not be so high as to induce overloading. An *rf* stage (or stages) used in this manner is generally referred to as a *preamplifier*. If associated with a tuned circuit (aerial circuit) it is better called a *preselector*, and when its tuning control is ganged with that of the oscillator and mixer its circuits must track with those of the mixer circuit. Alternatively the preselector may be made as a separate unit, often incorporating a tuned output circuit which gives further improvement in selectivity.

For extreme sensitivity, i.e. maximum signal-to-noise performance, a low-noise mixer is also desirable. Such circuits can be produced around special valves, or special transistors, and may even eliminate the need for a preceding *rf* amplifier. However, such an amplifier stage may well be used to improve selectivity, and still further improve sensitivity.

It can also be advantageous if a receiver has variable selectivity, since part of the circuit noise will be contributed by minute voltage variations always present across impedances, the most significant impedance being that of the first tuned circuit. The extent of this noise is largely governed by the passband width. In effect this implies that if the passband width is adjustable the best signal-to-noise ratio will be achieved when this control is set to its most selective position.

A further possible source of circuit noise is 'hum' injected into the circuit from the power supply. This, if present, is basically a matter of insufficient smoothing and filtering in the power supply circuit.

Oscillations generated in the circuit and heard as 'squeals' are due to circuit faults or failings. Oscillation in the high frequency oscillator or mixer circuits will show up as squeals as the tuning is altered. Oscillation developing in the *if* circuits is independent of tuning and will show up as a continuous squeal when the volume control is advanced with the beat frequency oscillator on. A mushy 'hiss' which varies with the tuning indicates that the high frequency oscillator is 'squegging' or oscillating simultaneously at low and high frequencies. These are dealt with on a trouble-shooting basis as a circuit fault.

There are also, of course, external sources of 'noise' which can interfere with the performance of a receiver. These fall under the categories of *natural* (atmospheric), or *man-made*. Only the latter are really 'treatable' and even then the effectiveness of such treatment is normally limited by the corresponding reduction in sensitivity acceptance.

A possible method of tackling this problem is to apply some form of automatic control which limits the amplitude of any intermittent or impulse type noise (interference) to that of the true signal being received. The signal is then passed at full strength, but the interference is 'chopped' so that it cannot exceed the strength of the true signal. The greater the amplitude of this type of interference, compared with its duration, the more effective this form of noise control becomes. It does not eliminate the interference, of course, but suppresses it without applying any suppression of the true signal.

Fig. 6.7. shows how such a noise limiting treatment applies to the *af*

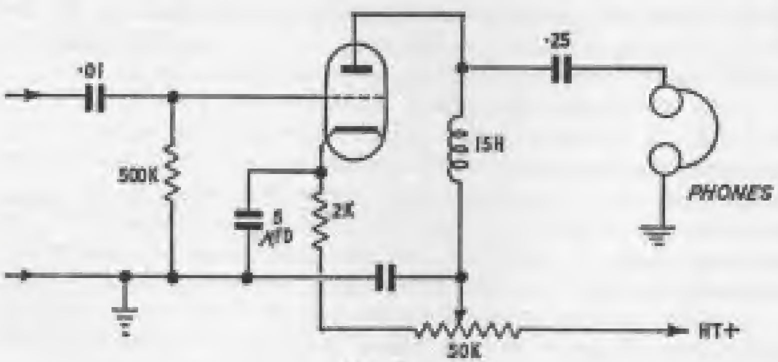


Fig. 6.7

(output) stage of a receiver. Systems like this are relatively simple and are adaptable to most receivers. However, the more the selectivity available in the preceding stages, the more difficult it is to provide satisfactory noise suppression at the output stage. For that reason it is often preferable to apply noise treatment at an earlier stage, e.g. at the first *if* stage of a superhet receiver before the high-selectivity circuits are reached.

An *if* noise silencer usually aims at using the noise pulses to decrease the gain of an *if* stage momentarily, thus applying silencing of the receiver for the duration of the pulse. Any noise voltage in excess of the desired signal maximum is taken off at the grid of the *if* amplifier, amplified by the noise amplifier stage, and rectified. This rectified noise voltage is then applied as a pulse of negative bias, wholly or partly cutting this stage for the duration of the pulse. Such circuits can be a bit tricky as regards stability requirements, and also require reasonably high input power to work most effectively (e.g. at least one stage of *rf* amplification preceding the mixer).

The design of noise limiters is, in fact, a fruitful field for experiment, and numerous designs have been published in the technical journals covering amateur radio construction. They are known generally as 'noise limiters', but may also be described as QRM (interference from other stations) limiters and QRN (interference from atmospherics or local electrical devices) limiters.

The need for noise limiters can vary enormously. Some receiving areas may be relatively noise-free, as far as man-made interference is concerned. Others may be heavily contaminated with interference from electrical devices operating locally, when the use of a noise limiter may be the only solution to obtaining any form of intelligible reception at certain times, or with certain stations.

Crystal Filters

Crystal filter circuits have become increasingly favoured on modern communications receivers in the *if* stage(s). They are normally used as interstage filters, but may also be used as a balanced input filter. The most common form is the so-called half-lattice arrangement, with its variants, with a tendency to increase the number of individual crystals employed for variable selectivity and to reduce irregularities in the pass-band, e.g. see Fig. 6.8.

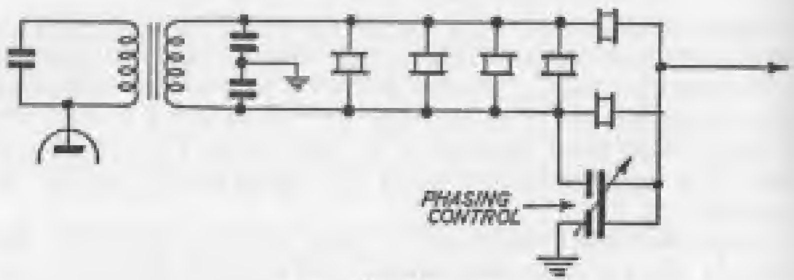


Fig. 6.8

For simple working, however, the bridged T-type of filter circuit may prove quite adequate. This comprises the basic network shown in Fig. 6.9. Capacitors C1 and C2 are adjusted to provide maximum response

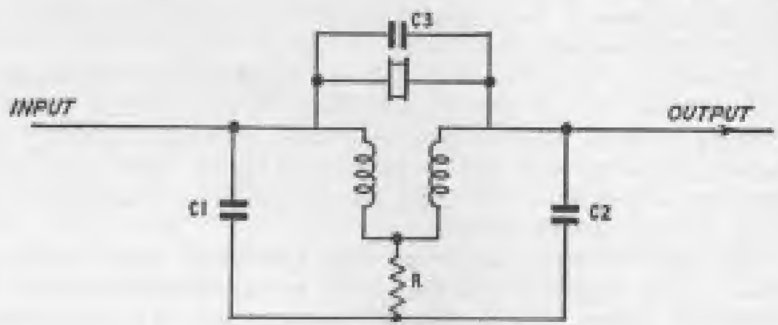


Fig. 6.9

at the series-resonant frequency of the crystal. The position of the maximum rejection points on each side of the crystal is set by C3.

Signal-strength Meter

A signal-strength meter, usually known as an S-meter, which shows relative signal strength is a useful form of tuning indicator. In order to provide a relative reading a milliammeter can be used in a simple bridge circuit, as shown in Fig. 6.10. The meter then shows the variation in anode current passed by the valve, compared with the fixed current passed by the two resistors.

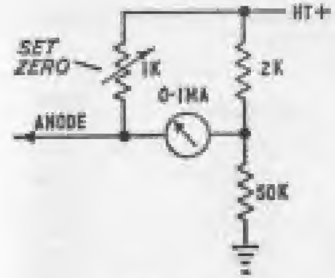


Fig. 6.10

The advantage of such a circuit is that the milliammeter is at a high potential. A rather better arrangement is that shown in Fig. 6.11, the same principle of reading in a bridge circuit applying.

For the amateur radio enthusiast, the receiver is probably more important than the transmitter. In other words where cost compromise is involved—and it usually is!—the preference should be towards buying the best possible receiver and accepting the compromise on the transmitter side, rather than trying to strike an overall compromise, or favouring the transmitter. This is particularly true in the case of the beginner, as the receiver will invariably give him more 'results' until he has become quite an experienced operator.

The choice should also be an amateur-band only receiver, as such a design will avoid the compromises necessary in an all-band receiver, however complex or elaborate the specification of the latter may be. Restricted band coverage is no real problem since the coverage of a receiver can be extended quite simply, and inexpensively, by the addition of a converter.

For accurate working a *crystal calibrator* is virtually essential and is commonly included in the design of a communications receiver. If not, such a calibrator can be added to the receiver (connecting to the *rf* amplifier stage).

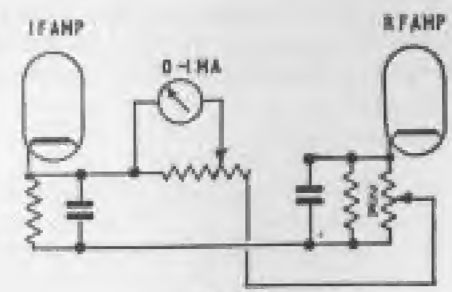


Fig. 6.11

Table 9. Typical Equivalent Noise Resistance Values of Valves
(For valves in new condition)

Amplifying valves	*e.n.r. ohms*	*Mixer valves*	*e.n.r. ohms*
6AC7	220*	6AK5	7520
	720	6BA6	14000
6AG5	1900	6BA7	60000
6AK5	385*	6BE6	190000
	1880	6J6	1880
6BQ7A	390	6K8	290000
6BZ6	1460	6L7	255000
6CB6	1440	6SA7	240000
6F23	670	6SB7Y	62000
6F24	370	12AT7	2400
6J6	470	12AU7	7280
6SG7	3300		
6SH7	2850		
6SJ7	5840		
6U8	295*		
	2280		
12AT7	380		
12AU7	1140		
12AX7	1560		

*Working as a triode

A crystal calibrator provides harmonics of a 100 KHz oscillator, thus providing a means of checking the receiver dial at every 100 KHz point through its tunable range. Where the original calibration is only approximate, or is affected by some instability during working, dial calibrations can be corrected at every 100 KHz point to obtain accuracy of frequency readings from the point to which the receiver is tuned.

CHAPTER 7

POWER SUPPLIES

THE basic method of obtaining a high voltage (*ht*) supply is to step up an *ac* mains supply via a transformer. At the same time the transformer can be tapped, or provided with separate windings, to produce any other lower or intermediate voltages which may be required. Voltage step-up, or step-down using a transformer is possible only with an alternating current input. The resulting output is also *ac*, from which it follows that further components will be required in a power supply to provide stepped-up or -down direct current voltages, such as required for the anode of a valve. Basically this involves *rectification* of the transformed voltage, with the addition of *smoothing*, if necessary, to remove any remaining 'ripple' in the *dc* output. *Voltage regulation* may also be necessary, even if only aimed at limiting the value of transient voltages which may be introduced in the power supply circuit. In that case we are concerned with the peak inverse voltages (p.i.v.) which may be developed as affecting the loading of the components. *Voltage regulation* itself can be expressed as a percentage, viz.

$$\text{regulation } (\%) = \frac{100(E_1 - E_2)}{E_2}$$

where E_1 is the no-load voltage (no current flowing in the load circuit).
E_2 is the full load voltage (rated current flowing in load circuit).

Three basic rectifier circuits are shown in Fig. 7.1. A single diode will provide half-wave rectification. Two diodes can provide full-wave rectification, with the circuit completed through the transformer centre tap. Alternatively the bridge type circuit may be used for full-wave rectification.

Either valves (diodes) or metal rectifiers can be used in such circuits. Metal rectifiers have the advantage that they require no heater supply, but have to be fitted with cooling fins to dissipate the heat generated by their relatively high forward resistance. Valves also get hot, and both need plenty of space within the cabinet and good ventilation. Power supplies of these types, therefore, tend to be heavy and bulky.

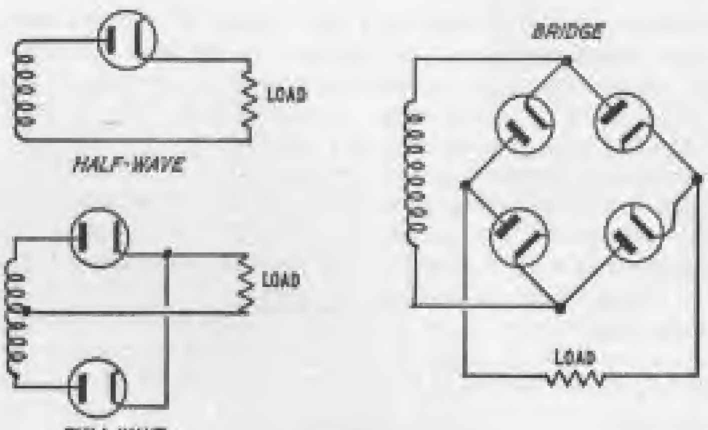


Fig. 7.1

Silicon power diodes are now generally preferred to valves or metal rectifiers. They can be produced in virtually miniature size, require no heater current, and have relatively low heating (and thus much higher efficiency), because of their very low forward resistance. Whilst this latter feature is highly desirable, it does also emphasize the potential weakness of the silicon diode to the possibility of high voltage surges developing which will destroy the diode. This is because of the relatively low p.i.v. values such diodes can withstand. Unfortunately, too, it is also a characteristic of silicon diodes that they tend to fail in a shorted condition, rather than 'open', so that failure of one diode in a series could readily cause the remainder to fail as well.

Series connection of silicon diodes is generally necessary to realize the p.i.v. rating required. This is decided basically by the p.i.v. likely to be developed by the rectifier circuit. In the case of a single diode circuit,

the p.i.v. across the diode will be approximately 1·4 times the *ac* voltage across the transformer coil. The centre-tap circuit will yield a p.i.v. of about 2·8 times the *ac* voltage across each half of the transformer coil. The bridge circuit will again yield about 1·4 times the voltage across the coil.

The required rating can be built up by connecting as many diodes in series as necessary to factor their individual ratings by 2, 3, 4 times, etc., allowing a suitable margin of safety. This, however, will only be valid if the diodes are exactly matched in characteristics (particularly their reverse resistance). This is unlikely in practice, and so equalizing resistors are normally connected across each diode—Fig. 7·2. Altern-

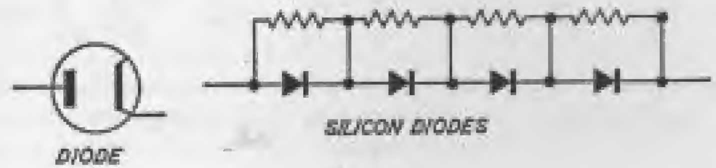


Fig. 7.2

atively, equalizing capacitors may be used in some circuits. Both configurations, incidentally, also act as transient suppressors to protect the diodes against surges of high current. Since capacitors are more effective in this respect, resistors and capacitors may be used in series across each diode as equalizing/damping devices. Further protection may also be incorporated in the rectifier circuit by including a fuse to open-circuit a chain of diodes in the event of overload, or failure of one of the diodes.

One other precaution which may be necessary with silicon diodes is to 'balance' their rating against temperature. Although they do not generate much heat themselves, their performance is temperature-dependent, and maximum rating applies with a temperature limit. If they are to be worked at a higher ambient temperature, derating of performance is necessary. Temperatures for maximum current rating may range from as low as 25 °C to as high as 70 °C, depending on type and manufacture. Derating, typically, is of the order of 10 per cent per 10 °C temperature rise above the rated temperature.

Filters

The output from a rectifier circuit is pulsating *dc*. To render this in the form of smooth *dc*, filtering must be applied. Whilst this may not be strictly necessary for valve operation, it is absolutely necessary to eliminate (or at least reduce) the 'hum' content of the power supply applied to various stages of a transmitter or receiver circuit.

Effective smoothing of the supply is readily achieved by means of a *capacitor-input filter*, which may be either single-section or two-section—Fig. 7·3. The single-section filter is generally adequate for transmitters,

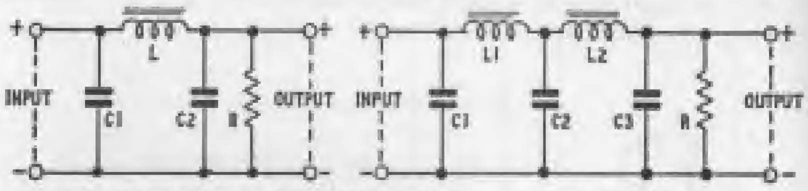


Fig. 7·3

but the two section circuit is preferable for receivers. The addition of a 'bleeder' resistor is generally recommended, its purpose being to discharge the capacitors when the power supply is not in use. The value of the bleeder resistance should be chosen so that it draws 10 per cent or less of the rated output current of the supply. (It can be calculated directly as 1000E/I ohms, where E is the output voltage, and I is the load current in milliamps.)

The ripple voltage remaining will be governed by the values of the capacitors and inductance. Typical values are 8 μfd for the capacitors (although C1 can be reduced to 4μfd in the two-section circuit), with an inductance of 20 to 30 henries. Ripple voltage will get smaller as capacitance and inductance are made larger. Few problems are imposed in matching component values, and satisfactory smoothing is readily obtained. Capacitor-input filter circuits, however, exhibit poor voltage-regulation properties when used with varying loads.

The *choke-input-filter* provides better voltage regulation, but less effective smoothing. Again it can be single-section or two-section—Fig. 7.4. The two-section circuit is generally superior as regards smooth-

ing. Note again the use of a 'bleeder' resistor to discharge the capacitor(s) when the power supply is not in use.

The first inductance can, with advantage, be of the 'swinging choke' type—that is, having 'swinging' characteristics over a range

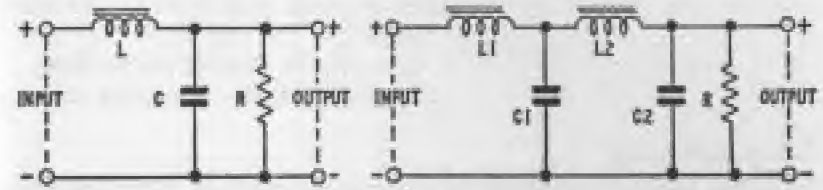


Fig. 7·4

of about 5 to 20 henries over the full output current range. The highest value will then apply when there is no output load on the power supply other than the bleeder resistor. The second choke should then have a constant inductance of 10 to 20 henries with varying *dc* load currents.

With this type of circuit it is possible to use capacitors with lower rated voltage than those necessary for a capacitor-input filter (which have to have a higher rating than the peak transformer voltage). However, a similar high voltage rating is usually advised, as in the event of failure of the bleeder resistor the voltages would rise to these peak figures.

Output Voltage

Basically, the *dc* output voltage is about 0·9 times the *ac* voltage across the transformer secondary in the case of a single diode or bridge circuit; and about 0·45 times the *ac* voltage across the transformer secondary in the case of the bridge circuit. With capacitor-input filters, the secondary *rms* voltage required is thus 1/0·9 or 1·1 times the required *dc* output voltage, to allow for voltage drops in the rectifier and filter circuits, and in the transformer itself. In the case of a centre-tapped circuit, this voltage must be developed across each side of the secondary centre tap.

With a choke-input filter circuit following the rectifier, the required transformer secondary voltage can be calculated directly from:

$$E = 1{\cdot}1\left(E_o + \frac{I(R1+R2)}{1000} + E_r\right)$$

where E = full load *rms* secondary voltage.
E = required *dc* output voltage.
(The open circuit voltage will usually be anything from 5 to 10 per cent higher.)
E_r = voltage drop in the rectifier.
R1, R2 = resistance in filter chokes.

Voltage Stabilization

A basic method of obtaining voltage stabilization is by the use of a voltage regulating tube in series with a limiting resistor, as shown in Fig. 7.5. The initial (unregulated) voltage needs to be higher than the

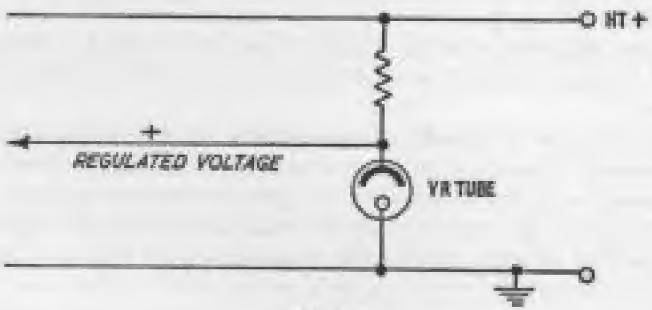


Fig. 7.5

starting voltage of the tube, which is usually about 30 per cent higher than the operating voltage. The value of the limiting resistor is chosen to just pass the maximum tube current when there is no load current. With load added, the tube can then work down to its minimum current condition. Within this range the voltage drop of the tube is constant, thus providing a point for tapping off a stabilized voltage. Voltage regulation better than 10 per cent can readily be achieved; and with the tubes in series, stabilization is further improved down to about 1 per cent. The use of two tubes in series also enables two different values of regulated voltage to be tapped, one from each tube.

Fig. 7.6 shows how Zener diodes can also be used to stabilize a high

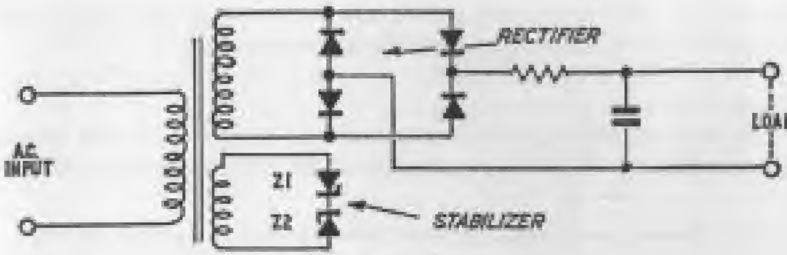


Fig. 7.6

tension supply obtained from a mains transformer. The low voltage Zener diodes (Z1 and Z2) are simply connected in back-to-back configuration across a low voltage winding on the transformer.

Bias Voltages

Bias supply requirements are basically a fixed voltage of the required value to set the operating point of a valve. The output should be well filtered, and capacitor-input filters are commonly preferred. A bleeder resistor is effective as a voltage regulator since it provides a *dc* path from the grid to the cathode of the valve being biased. However, to be really effective this will need a low resistance value so that the current flowing through the bleeder resistor is several times the maximum grid current to be expected, which is wasteful of power.

In particular cases, therefore, it may be expedient to adopt more efficient methods of bias voltage stabilization. Two such stabilizing circuits are shown in Fig. 7.7. One uses a triode as a regulator, and the

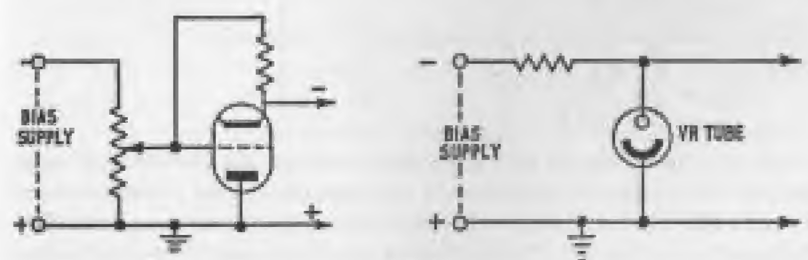


Fig. 7.7

other a VR tube. The latter is only applicable where the voltage and current ratings of the tubes permit their application.

Voltage Dividers

The conventional type of voltage divider is based on the circuit shown in Fig. 7.8. Basically it comprises a series of resistors (or a resistor

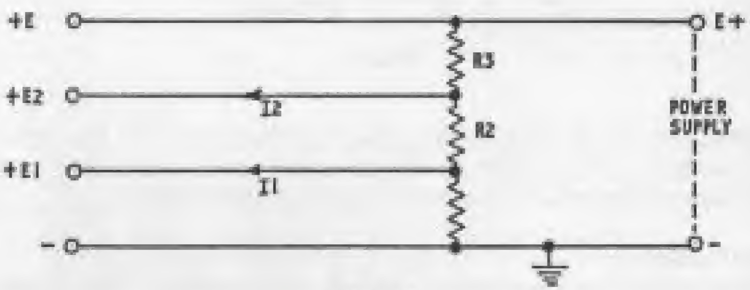


Fig. 7.8

with a series of tapping points), from which voltages lower than the input voltage can be drawn by connecting to an appropriate tap. The end resistor is considered only as a 'bleeder', carrying a bleeder current which is normally 10 per cent or less of the total load current. The values of resistors required then follow from:

$$R1 = \frac{E1}{I_b}$$

$$R2 = \frac{E2 - E1}{I_b + I_1}$$

$$R3 = \frac{E - E2}{I_b + I_1 + I_2}$$

Voltage regulation is very poor with voltage dividers of this type because the voltage taken from any tap depends on the current drawn from the tap (and will thus vary with varying load). Thus, whilst they are suitable for constant load applications, additional voltage regulation would have to be applied for stabilization with varying loads.

Voltage Multipliers

Rectifiers can also be used as voltage-multipliers, in integer factors—a fact which can often be used to advantage. It is possible, for example, to accept an *ac* input direct into a rectifier circuit, without having to employ a transformer, and obtain both rectification and voltage doubling. Such a circuit is shown in Fig. 7.9. Each capacitor is charged

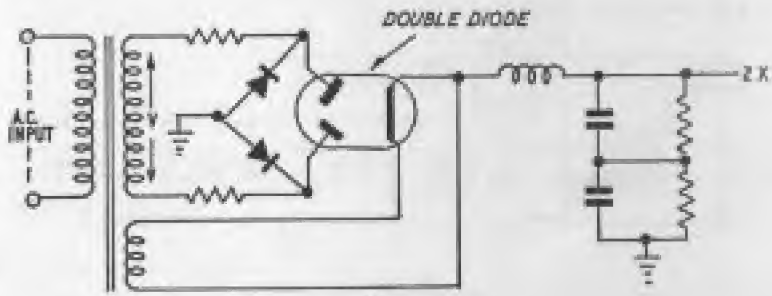


Fig. 7.9

separately to the same *dc* voltage from the two diodes and then discharged in series into the same load circuit (thus doubling the *dc* output voltage obtained).

Fig. 7.10 shows an extension of this principle, utilizing four diodes.

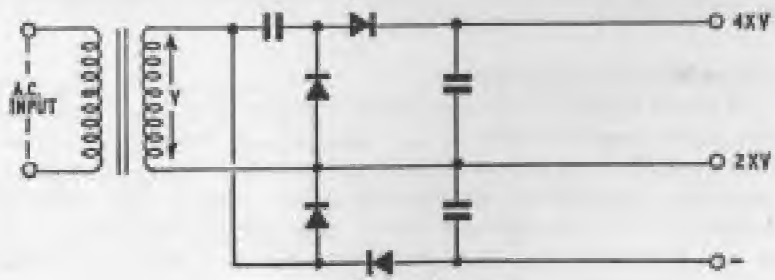


Fig. 7.10

The output from this circuit provides both voltage doubling and voltage quadrupling.

As with voltage dividers, voltage multipliers tend to offer poor

voltage regulation, although this is less marked with silicon diodes as compared with diode valves and metal rectifiers.

Variable Voltage Supplies

A simple type of variable voltage supply for use with a constant voltage power supply is shown in Fig. 7.11. This circuit eliminates

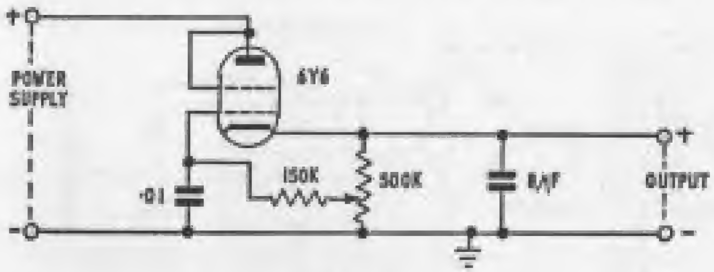


Fig. 7.11

series resistors as a source of voltage drop and as a consequence maintains a substantially constant source impedance. Voltage regulation is also provided, as well as voltage variation via the variable resistor, although the degree of stabilization will deteriorate with increasing voltage output. It is, however, another example of how simple circuits can often be used to provide solutions to particular requirements in transmitter and/or receiver working.

Stabilizer Valve Heater Supplies

The heater supply for valves tends to be regarded as non critical, and conveniently supplied direct from a separate low voltage coil on the mains transformer, without rectification. As a minimum precaution, it is generally desirable to use separate heater supplies (e.g. separate transformer coils) for oscillator valves, and voltage stabilization may well also be considered as a method of further improving the overall stability of the stage(s) involved.

A simple circuit which offers considerable possibilities in this respect is shown in Fig. 7.12, employing two Zener diodes in back-to-back bridge circuit configuration. The variable resistor acts as a trimmer to set up the circuit, its value being about 20 per cent of the total resistance

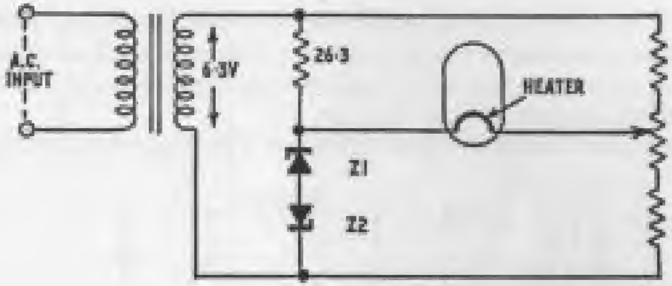


Fig. 7.12

value of the lower arm of the bridge. Voltage stabilization of better than 1 per cent is claimed for this circuit, with a transformer voltage change of up to 13 per cent.

Transistor Power Supplies

Transistor circuits require only low voltages and thus considerably simplify power supply requirements, particularly as only a single voltage is usually required. They may, however, be fed from a mains supply, in which case similar requirements apply as regards rectification and smoothing, following the mains transformer. For voltage stabilization, a Zener diode is normally employed (the Zener diode is virtually the counterpart of the VR tube in higher voltage circuits).

A typical modern transistor power supply circuit is shown in Fig. 7.13.

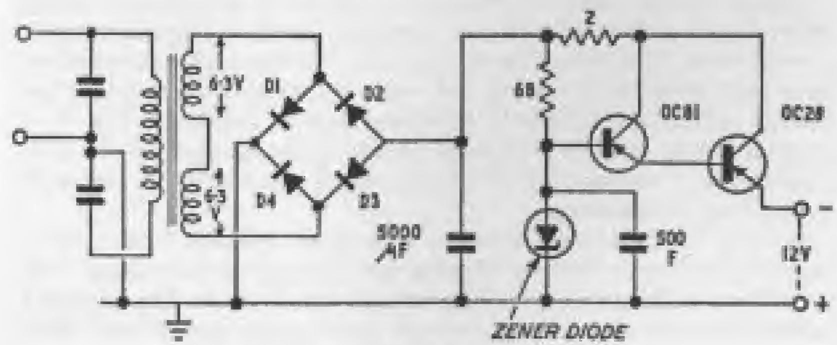


Fig. 7.13

which is also notable for incorporating electronic smoothing. There are numerous variations on a similar theme but, in general, shunt regulation is taking preference over series regulation, as this will permit the output to be short-circuited without damage.

A very much simpler system is shown in Fig. 7.14, which merely uses

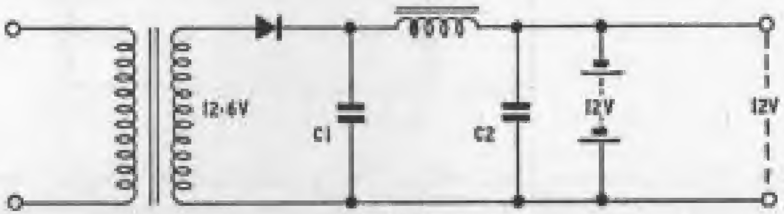


Fig. 7.14

half-wave rectification followed by smoothing and a battery of the same voltage as the *dc* output 'floating' across the output. This battery provides extremely good stabilization and at the same time can also act as a ripple filter. Capacitor C2, in fact, is not really necessary. Basically, in fact, the battery provides an additional source of power to combat voltage drop under load. A similar system of 'floating' a battery across the output can equally well be applied to a full-wave rectifier output. Zener diode stabilization can also be added, if necessary, for an even higher degree of stabilization.

Stabilization is less readily provided across a direct battery feed to a transistor circuit since conventional methods of stabilization using Zener diodes and resistors almost inevitably mean a large increase in current drain, further loading the batteries. Various ingenious solutions have been proposed to combat this, such as the use of current-limiting circuits (which also safeguard transistors against overload). Fig. 7.15 shows a simple low-loss stabilizing circuit, based around the use of a transistor as a constant current device, which can readily be extended to two stages if necessary.

It may be remarked, however, that good stability from battery supplies can be provided by choosing specific types of low voltage cells which have substantially parallel load/life characteristics. Conventional Lechlanche-type dry cells are basically poor in this respect and other types are generally to be preferred, if bulk is not a primary considera-

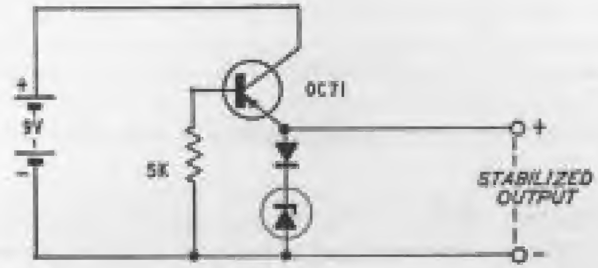


Fig. 7.15

tion. Layer-type Lechlanche-type dry batteries, for example, come in convenient, small 'packages' for 9-volt supplies, up. An equivalent battery in, say, nickel-cadmium cells, would be very much larger.

CHAPTER 8

AERIALS

BASICALLY any aerial is a wire through which *rf* currents flow, these currents either being fed directly into the wire from a transmitter for broadcasting or collected by the wire itself from emissions present in the vicinity of the aerial. To consider the performance of an aerial in any detail it is first necessary to consider the factors which affect the propagation of radio frequency waves. Such waves, as has already been explained (Chapter 1), radiate from a source with the speed of light, with *frequency* and *wavelength* inversely dependent. Such waves are, however, subject to:

1. *Polarization* which also affects the *directivity* of the waves. This is usually determined with respect to the lines of force in the electrostatic field. If these are vertical or perpendicular to the earth's surface the wave is said to be vertically polarized. If parallel to the earth, the wave is said to be horizontally polarized. The electro-magnetic component is at right angles to the electro-static component, and so the lines of force of the electro-magnetic field are horizontal with a vertically polarized wave and vertical with a horizontally polarized wave.
2. *Reflection*—at surfaces of discontinuity, such as the surface of the earth, and at different layers of ionized air present in the earth's atmosphere.
3. *Refraction*—specifically when passing through the ionized layers in (2).
4. *Diffraction*—or bending of the waves caused by passing some form of barrier at a shallow angle.

Significant aerial parameters are:

Angle of Radiation. This is the effective angle over which the *rf* is radiated, measured in a vertical plane with respect to a tangent to the earth's surface at the transmitting point. It is not necessarily a well defined angle, but more a broad angular region, depending on the type

of aerial. The angle of radiation is also determined by the polarization, height above ground and the nature of the surrounding ground.

Directivity—or the pattern of power radiation. All aerials tend to radiate more power in certain directions than others and thus have directivity in both vertical and horizontal planes (and all intervening planes).

Two types of waves are actually produced by a radiating aerial, one of which travelling along the surface of the earth is called the *ground wave*, e.g. *see* G, Fig. 8.1. The ground wave must be vertically polarized

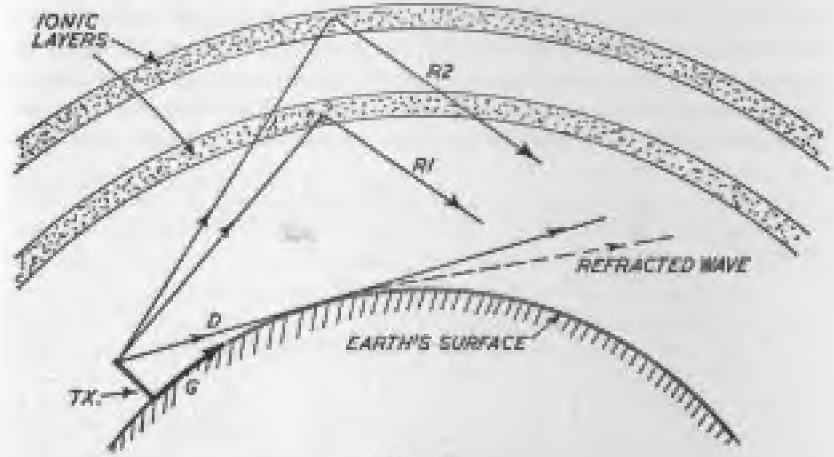


Fig. 8.1

in order to induce a current in the ground travelling along its surface. The range of such a wave depends on the nature of the ground (less energy is lost travelling over the surface of water than land, for example) and the frequency of the wave. At higher frequencies the range drops very rapidly, and so the ground wave is relatively useless for frequencies above about 5 MHz.

Air waves (or sky waves) may be transmitted direct (e.g. *see* D in Fig. 8.1), or be reflected off an ionic layer in the earth's atmosphere—R1. There is also the possibility of an air wave passing through one layer (where it will be subject to refraction), and then being reflected off a higher layer—R2. Note also that in the case of a direct wave (D)

there may also be a component reflected off the earth's surface; also the range may be extended beyond 'line of sight' by refraction.

Ground waves are largely free from external 'interference', although their significance can largely be discounted for amateur transmissions. Direct 'line of sight' air waves are liable to be affected by local areas of atmospheric disturbance, which can also affect the extension of range which may be provided by refraction. Reflected air waves are much more liable to seasonal, daily, and in some cases even hourly variations due to changes taking place in the ionized belts.

Rather than get too involved in the technicalities concerned—which are worthy of separate study by the serious amateur radio enthusiast—it is best for a simple study to consider optimum conditions in terms of *wave angle* and other requirements which may affect the performance at specific transmitting frequencies. We then largely have the general range conditions shown in Fig. 8.2. The ground wave will give reception

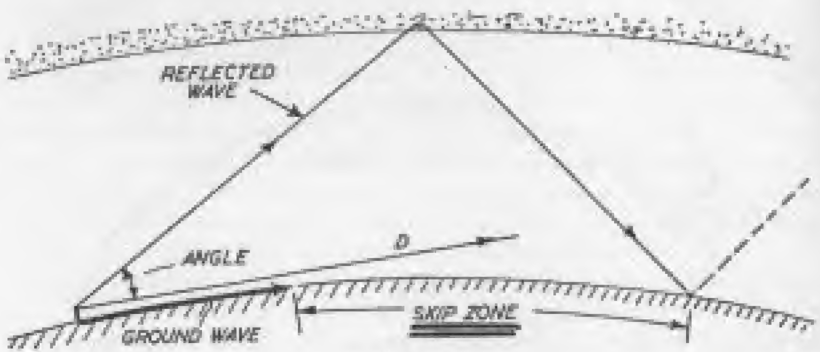


Fig. 8.2

over a relatively short distance, after which the signals will be too weak to be of much use. Depending on the wave angle (and the layer from which the air wave is reflected), there will then be a zone known as the *skip zone* where the signals will be very weak, until at some greater distance the reflected wave returns. Considering the separate bands:

1·8 MHz. Low angle radiation is best for longest distance. High angle radiation will cause fading towards the end of the ground

wave range. Waves at all angles will, however, be generally reflected and so the extent of the skip zone will be dependent on specific limitations to angle of radiation. Vertical polarization is generally to be preferred.

3·5 MHz. Basically the same as for 1·8 MHz, with again a favouring of low angle radiation for maximum range. Polarization is relatively unimportant.

7 MHz. Angle of radiation is best limited to 45 degrees as most higher angle radiation will not be reflected. Higher angles may, however, be used effectively during sunspot activity. Horizontal polarization is to be preferred, but this is not usually a significant factor.

14 MHz. Angles of radiation should be below 20 degrees for maximum range, but may be reduced for shorter distances. Maximum angle (beyond which reflection is lost) is about 30 degrees. Polarization is not significant, although horizontal polarization is preferred.

28 MHz. Low angles of radiation are preferred for maximum range, e.g. not more than 10 degrees. Losses are high with higher angles. Polarization is not important as far as performance is concerned, but may have some bearing on TV interference. The main thing as regards polarization is that it should be the same at both transmitter and receiver.

70 MHz. The lowest possible angle of radiation is to be preferred. The same comments as for 28 MHz apply as regards polarization.

Frequency and Efficiency

Considering an aerial wire of infinite length, the application of *rf* to one end will result in the formation of standing waves of *rf* along the aerial length—Fig. 8.3

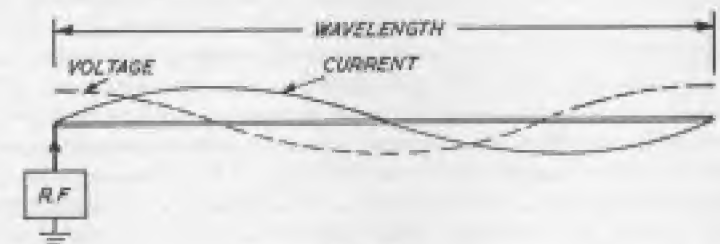


Fig. 8.3

Any practical aerial must necessarily have a finite length, the effect of giving the aerial a definite end being to induce a reflection of current back from that end. These reflections will thus superimpose themselves on the standing waves, producing a measure of amplitude increase or decrease, depending on the phase difference present.

The most significant effect is produced when the aerial wire is one half wavelength long. The effect is to yield two current peaks coincident at the centre, yielding the typical *rf* current and voltage distributions shown in Fig. 8.4. Since the field strength produced by the aerial is

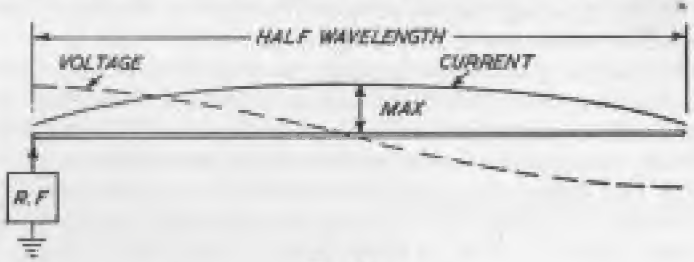


Fig. 8.4

directly proportional to the *rf* current present, this represents an optimum condition. It also follows that the length of aerial required can readily be calculated as one half the wavelength of the *rf* signal to be transmitted, referred to as the resonant aerial length.

Such an aerial is known as a *half-wave aerial*, more popularly called a *dipole* (also sometimes variously known as a Hertz aerial or doublet). It forms the basis of a number of practical aerial designs, and also a standard for comparison of performance of any other type of aerial.

The free space radiation pattern of such an aerial is shown in Fig. 8.5. The circles are representative of solid 'lobes' of radiation, from which the directivity is fairly obvious. For example, maximum radiation is at right angles to the wire, with zero radiation along the direction of the wire itself. Thus if the aerial is vertical with respect to the earth's surface, field strength will be a maximum in a horizontal direction, and uniform in all horizontal directions. If the aerial is horizontal, then the relative field strength will depend on the direction of the receiver relative to the transmitting aerial wire orientation. In practice, of course, the actual radiation pattern can be modified by reflection from

the ground, but these will only affect downward inclined radiations. This effect can be used to reinforce the air radiations at the most desirable angle—the lower the radiation angle required, the higher the aerial should be.

It would also appear at first sight that vertical arrangement of the aerial would be preferable to horizontal since this would concentrate

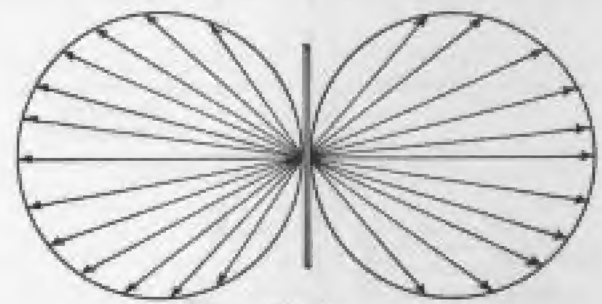


Fig. 8.5

the radiations horizontally. However this will also increase the ground losses (particularly at higher frequencies) and so overall there is little difference in cases where polarization is not important. A long horizontal aerial is also easier to erect than a similar length of vertical aerial. The main limitation with the horizontal aerial is that it will show increasing directivity effects with increasing frequency, where the angle of effective radiation becomes increasingly less.

The actual resonant aerial length required refers to the effective electrical length rather than the physical length of the wire. The electrical length is arrived at by deducing an 'end correction' from the calculated physical length, this quantity normally being taken as 5 per cent of the calculated physical length—*see* Table 10. In general this length is calculated for the mid-frequency of the band involved and the appropriate dedendum applied, depending on the type of aerial. The same treatment applies for other resonant lengths, e.g. full-wave or quarter-wave aerials. There is not normally much call to use a full-wave aerial, although a quarter-wave aerial may be convenient where it is necessary, or desirable, to reduce aerial length.

In this case a vertical aerial is generally best, connected directly to

earth through the tuned circuit—Fig. 8.6. In working this provides a 'mirror image' effect, equivalent to doubling the aerial length. Horizontal quarter-wave aerials can, however, be similarly effective. Grounded aerials are particularly useful for lower frequency working (e.g. 3·5 MHz and particularly 1·8 MHz), to avoid the excessive wire

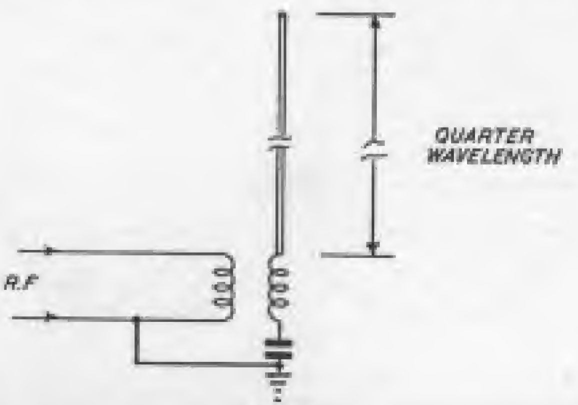


Fig. 8.6

lengths which would otherwise be needed for half-wave aerials. They are also particularly popular for vertical *vhf* aerials, especially on receivers or transceivers, although their efficiency in such cases can be greatly reduced if the set is not connected to an efficient external earth.

Multi-band Aerials

The subject of 'optimum' aerial design is complex and needs considerable study, and experimental verification. The relative newcomer to amateur radio work is well advised to stick to simple, established designs, such as the dipole, and aim at the best possible siting (determined by practical tests, if necessary).

A well proven 'standard' design for a multi-band dipole is shown in Fig. 8.7. If the length L is made 51 ft. (15·55 metres), or one half this value if space is restricted, good reception should be possible on all bands from 1·8 MHz to 28 MHz. The corresponding length of the feeder section is 34 ft. (10·36 metres) for an open wire feeder; or 29 ft.

6 in. (9 metres) if a 300 ohm ribbon feeder is used. (A half-length aerial would use half these feeder lengths.) Connection to the transmitter from the bottom of the feeder to the aerial tuning lead can then be made by any length of 80 ohm coaxial cable, up to a maximum of about 100 feet.

Such an aerial will, of course, be directional, since it is a horizontal dipole. If necessary, two or three such aerials can be erected in different

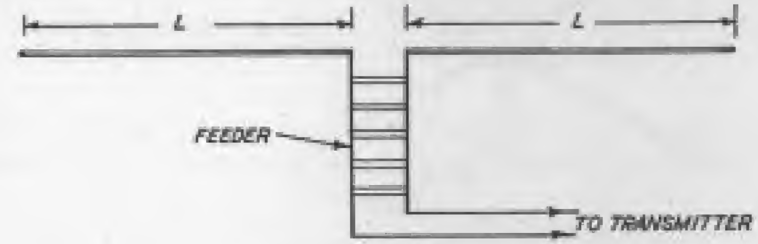


Fig. 8.7

alignments, arranging to switch the transmitter (or receiver) from one to the other to explore directional possibilities.

There are, of course, many other forms of directional aerials, and much more compact types can be used for *vhf*, e.g. television type aerial arrays.

Directional aerials

Remaining with simple aerial designs, the vertical dipole has omnidirectional characteristics, the chief limitation being the height required for half-wave resonance at short-wave frequencies. This can be halved by adopting a quarter-wave resonant length.

The so-called ground-plane aerial is also widely recommended for multi-directional DX (distance) working. This comprises, basically a single half-wave resonant vertical length, or radiator, with four radials arranged at 90 degrees in a horizontal plane, or slightly angled downwards—Fig. 8.8. These radials are also of half-wavelength length, but uncorrected (no dedendum). The feedpoint impedance varies with the slope of the radials; so the impedance of the coaxial cable must be selected accordingly, or the slope adjusted to arrive at a matching impedance (increasing the downward slope of the radials increases the

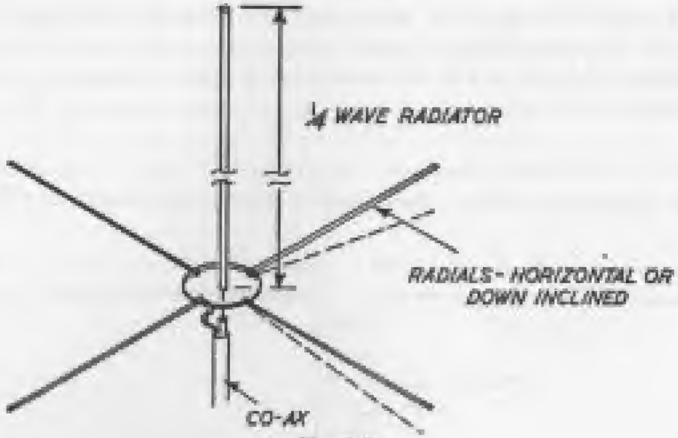


Fig. 8.8

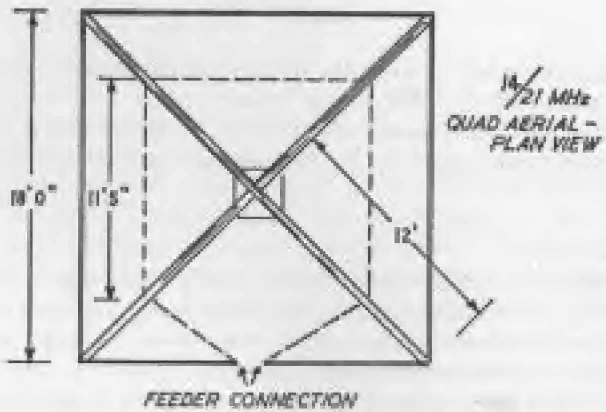


Fig. 8.9

impedance). With horizontal radials the impedance is of the order of 20–30 ohms on a 14 MHz half-wave resonant aerial, (16 ft. 11 in. radiator length).

Another simple type of directional aerial is the simple quad, comprising a single loop or double loop of wire in square configuration, preferably rotatable—Fig. 8.9. The dimensions shown are consistent

with 14 MHz and 21 MHz working. The double loop arrangement is preferred for greater gain. The coaxial cable connecting to the aerial should have an impedance of at least 75 ohms, and preferably a somewhat higher value.

Feeder Lines

Transmitter circuits are normally designed to give maximum power output feeding into a load of about 70 ohms (e.g. 72 ohms is a widely used value). Lines connecting the *rf* transmission to the aerial can be either non-resonant or resonant. In the former case adjustment is

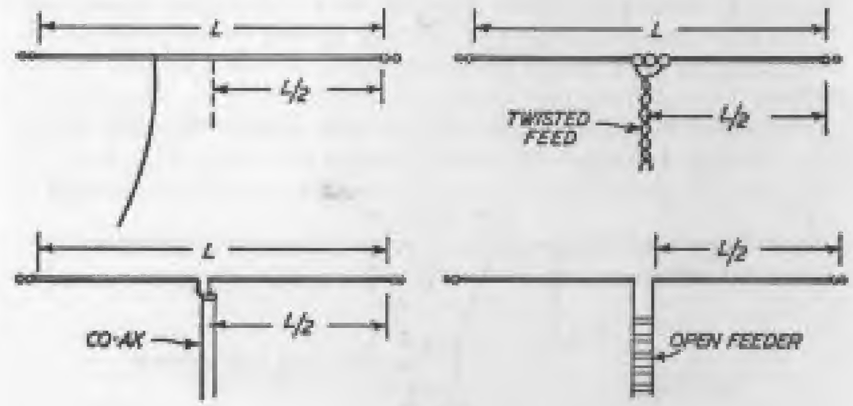


Fig. 8.10

merely a matter of adjusting the terminating resistance to match the characteristic impedance of the line, the aerial itself being resonant at the required frequency and the line so connected that the aerial impedance 'seems' the right value when looked at by the line. Matching is, however, only possible for one frequency (equivalent in practice to a narrow frequency band), so that such a system is only suitable for working on one band.

Some typical non-resonant feeds are shown in Fig. 8.10. With a single-wire feed the attachment point can be critical and also the feeder must run away from the aerial at right angles for a substantial distance in order to avoid interaction. A very good earth connection is also

necessary for satisfactory operation. With twisted wires, centre attachment is possible, the wires being selected to have a surge impedance equal to the *circa* 70 ohms impedance at the centre of the aerial itself. Adjustment of impedance match can be attempted by untwisting and 'fanning' of the wires where they join the aerial.

Both these simple systems have a number of limitations and a 70 (or 72) ohm co-axial feed is generally to be preferred. The outer conductor can be earthed, if desirable, to form a screen.

Open feeders may also be used, although here there is a difficulty in matching the impedance to that of the transmission line. Some proprietary feeders of this type may be available with an impedance of 70 ohms, but home-made feeders normally have much higher impedance due to the necessity of employing practical spacing for the two wires. In this case some other means must be adopted to match the line to the aerial.

One solution, again, is to fan out the ends of the feeder (Fig. 8.11),

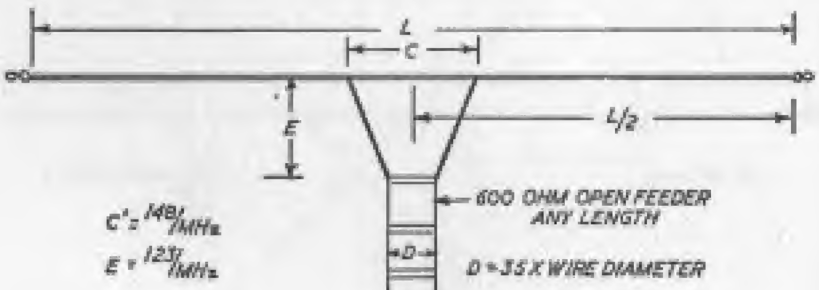


Fig. 8.11

although a more satisfactory solution is to use the impedance-transforming properties of a quarter-wave line. This system is generally known as a Q-aerial—*see* Fig. 8.12—comprising a quarter-wave impedance matching section with close spaced conductors.

Two-wire *resonant line* configurations are shown in Fig. 8.13. The basic advantage offered by such systems are simplicity of adjustment and considerable flexibility as regards the frequency range over which such systems will operate. Either quarter- or half-wave resonant lines can be used as feeders, although with a suitable aerial tuner neither this

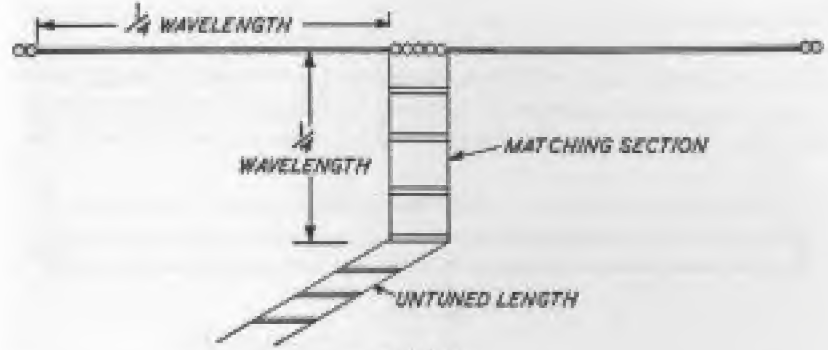


Fig. 8.12

length nor the aerial length is critical. Any marked departure from resonant aerial length can, however, upset the balance of the feeder. The end-fed type with resonant feeders is generally known as a Zepp (Zeppelin) aerial.

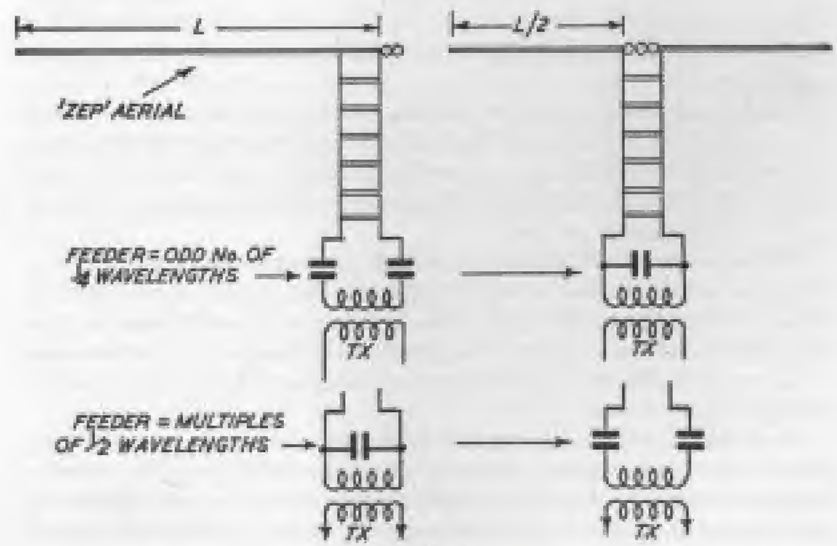


Fig. 8.13

Other Aerial Types

Various other types of aerials may be used. The subject is, in fact, one which admits of considerable experiment and development, particularly to find an optimum solution to suit local conditions. Folded dipoles are attractive, for example (Fig. 8.14), using 300 ohm ribbon feeder for the

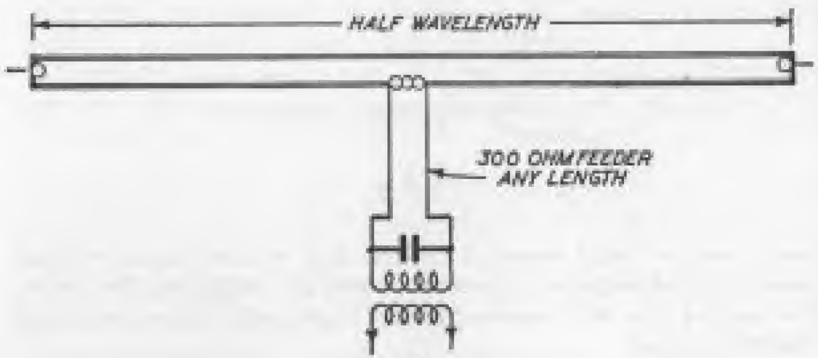


Fig. 8.14

dipole itself for an inside (loft) aerial. Multi-band dipoles are a further possibility.

Multi-band operation is also possible on many simple aerials, merely by adopting the principle of operating on harmonic frequencies, e.g. working with multiples of a quarter-wavelength equivalent resonant length. The method of feed may or may not have to be changed, depending on the harmonics involved.

The case of a simple single-wire aerial can be quoted as an example. Designed as a half-wave aerial for 3·5 MHz the actual length required would be approximately 130 ft. This could equally well be operated as an end-fed aerial on 7, 14, 21 and 28 MHz; and as a quarter-wave aerial on 1·8 MHz, in which case series tuning would have to be used—*see* Fig. 8.15.

For further information on the specialized subject of aerial design, consult the more advanced technical works available. The relative beginner setting up his transmitting station would be well advised to seek the practical advice of a local expert or more experienced amateur radio enthusiast. This can apply equally well to receiving aerials.

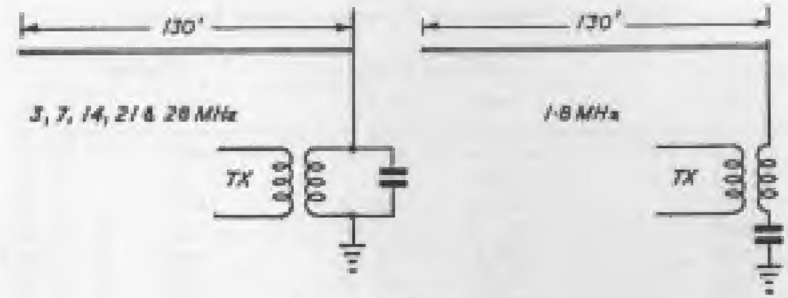


Fig. 8.15

Receiving Aerials

Basically all the properties of a radiating aerial apply to receiving aerials, and the optimum design of a receiving aerial would be based on similar characteristics to that of a particular transmitter. This can be particularly significant where directivity and polarity are important. However, a receiver aerial is likely to be called upon to cover a much broader range.

The simplest form of receiving aerial is merely a wire of no specific length. This acts as a conductor for a wide range of radiated waves. Basically the longer the wire the greater the energy extracted by the aerial, but this need not be carried to extremes. Because of the high sensitivity of modern receivers relatively short aerial lengths can be quite effective. Performance can, however, be improved considerably by the use of tuned aerials because of the greater signal-to-noise ratio provided.

In a complete station, it is usually convenient to use the same aerial for both transmitting and receiving. This will be a tuned aerial as regards the band(s) or direct interest, and logically erected under optimum conditions. A simple change-over switch can then transfer the aerial connections from transmitter to receiver, and vice versa.

There are cases, however, where a separate receiver aerial may be preferable, e.g. in the case of a directional aerial. It will be better from a receiving point of view if this aerial is designed to be extremely directional at the expense of gain. This will improve the signal-to-noise ratio, leaving the receiver circuit itself to provide all the necessary gain.

Table 10. Half-wave Resonant Aerial Lengths

Frequency MHz	*Arithmetic ½-wave*			*Dedendum**		
	metres	*ft.*	*in.*	*metres*	*ft.*	*in.*
1·8	85·700	281	2	4·267	14	0
3·5	42·850	140	7	2·134	7	0
7·0	21·412	70	3	1·067	3	6
14·0	10·719	35	2	·533	1	9
14·1	10·643	34	11	·533	1	9
14·2	10·566	34	8	·533	1	9
21.0	7·137	23	5	·356	1	2
21·1	7·112	23	4	·356	1	2
21·2	7·087	23	3	·356	1	2
21·4	7·010	23	0	·356	1	2
28·0	5·359	17	7	·254		10
28·4	5·283	17	4	·254		10
29·0	5·182	17	0	·254		10
70	2·134	7	0	·203		8
144	1·040	3	5	·102		4

* To be deducted from arithmetic length to arrive at true length required allowing for end correction. *Note.* End correction does not apply in the case of a Zepp aerial.

CHAPTER 9

OPERATING AN AMATEUR STATION

FUNCTIONAL requirements of any operating station are that the receiver and transmitter should be located in such a way that the controls are readily manipulated and 'read', as necessary, with the equipment also located so that there is a minimum of delay in changing from transmission to reception, and vice versa. The space in front of the equipment should be uncluttered, leaving room for the proper location of a key for *cw* transmission—plus space for taking notes, etc.

Thousands of words can be—and have been—written about this subject of 'layout'; whether the receiver is best located to the right of the transmitter rather than the left (for a right-handed operator), and so on. But basically this is an individual problem, affected by such factors as the bulk of equipment involved, space available, and whether or not a permanent layout is to be planned from the start.

The best type of layout is usually one which can be derived by 'trial and error' methods: *trying* which positions seem best for the equipment, arranged in the available space and based around a table or bench at which the operator sits. Aim for a *logical* arrangement which avoids excessive or uncomfortable arm movements, or crossing movements of the arms. Try to make every operation involved as *easy* as possible.

No rigid initial plan will provide the best answers to all these problems; and even experience will not necessarily show where changes are desirable. As a 'controller', the human being readily adapts and conforms to necessary movements, even if these involve a degree of discomfort or strain. The body will then tolerate these conditions, even though working efficiency may be impaired. Look for these 'physical snags' when first setting up the station!

Certain devices can also be incorporated to improve efficiency. Dials may be easier to read if angled slightly towards the operator, for example. Changeover from transmission to receiving, and vice versa, can be speeded by arranging this to be accomplished by the key itself for *cw*; or by a voice operated changeover device (VOX) for telephony

(although a push-to-talk switch on a microphone is probably as good). Some operators prefer a foot-operated switch for changeover—although this does not fit in so well with the lounging attitude many operators soon find themselves adopting for telephony.

Working technique

The golden rule for all novice operators with their first transmitter is to be a 'listener' first. Become familiar with the standard procedure—calls and answers—before being tempted to project your own signal to unknown listeners. This is particularly important if you are operating on telegraphy, where the language is code, with the emphasis on the use of abbreviations. Familiarity with the code abbreviations is *essential* for proper communication, although it will take some time before familiarity with all the abbreviations is mastered. At least study and master the main ones likely to be used, and required, first.

Note, too, how code is also used in telephony. A station calling and asking for anyone hearing him to reply, says, typically—"CQ CQ CQ. This is WXYZ" (the call sign of the station transmitting), which he may (or should) follow by speaking this phonetically, and terminate with "Over". (He may interpose the locality of the station before 'over'). The corresponding *cw* call would be:

CQ CQ CQ DE (a separation sign) WXYZ (the call sign) K (for 'over').

Calls should be kept short (say calling for about 10 seconds or so, followed by a similar period or slightly longer of listening for a reply). But before *any* call is made a period of listening should be observed first in order to check that the particular frequency is not already in use. Listen long enough to cover a typical 'call and reply' period. The original caller may be out of range, but a replying station may not, and you could break in on the reply with your call.

Answering a CQ should follow similar brevity, using abbreviated code on *cw*, and code letters and a minimum of words in telephony. Also follow any instructions which may be given regarding answering frequency.

A reply takes the form of a brief acknowledgement. Basically:

"WXYZ" (repeating the calling station call sign)—"this is ABCD" (the receiving station call sign), which can then be repeated phonetically in voice; and finally "over" (or K in telegraphy).

The only elaboration on this likely to be necessary is a repetition of your own call sign to give him a second (or in poor conditions possibly a third) chance to make a note of your station. In the case of DX, then locality could be added to your call sign.

Nothing more is needed. The contact and 'introductions' have been made.

Generally a CQer is looking for a reply on the same frequency on which he is transmitting. To be sure of this the (answering) transmitter can be 'spotted' on this frequency by zero beating the received signal with the transmitter *vfo*. The method used depends on the design of the transmitter, the type of emission involved, and the characteristics of the receiver.

This may also have to be done in reverse, working on *vhf*. If the replier is using a crystal controlled transmitter, for example, he will probably not be on the exact frequency and may have no means of 'spotting' his transmitter. In that case the original sender may first have to 'hunt' on either side of his original frequency to locate the answering call, when he can conveniently spot his own transmitter on that frequency.

Transmitter spotting is becoming an increasingly important technique to learn and apply as frequency stability becomes a more important feature of equipment design, and receiver designs become more sharply peaked. Transmitter spotting must, however, always be conducted with the transmitter off the air (i.e. the aerial isolated in such a manner that it is not radiating a signal during the spotting adjustment) to avoid 'sweeping' the band concerned with interference.

Transceivers simplify operation to a considerable extent, not only because of the greater compactness of the equipment but also because the transmitter frequency is locked to the receiver frequency. This means that tuning in the receiver to a particular frequency will also lock the transmitter on to this frequency. Thus the two stations in contact are operating on precisely the same frequency without the necessity of 'spotting' the transmitter, or using extra band space.

When designed as *ssb* voice transceivers, however, this automatic 'spotting' does not necessarily apply to *cw*. A tuned-in *cw* transmission will very likely be heard as a note, indicating that the signal is off-frequency as far as the receiver *bfo* is concerned. Retuning to transmit on the true frequency of the *cw* station will then throw the receiver off

frequency to the point where the incoming signal is zero beat with the receiver *bfo*, and no signal may be heard at all. To overcome this, some transceivers are provided with a separate control, often called a 'delta tuner' to enable the receiver frequency to be varied by a few kHz without changing the transmitter frequency. The transmitter can then be accurately 'spotted' whilst retaining independent frequency tuning of the receiver over the limited range required for satisfactory *cw* reception.

Brevity should be maintained once contact is established. It is good general practice to limit single transmissions to not more than about thirty seconds at the most, or shorter than this if the necessary topic or message can be put over intelligibly. Long messages—even in telephony—can result in part not being assimilated by the receiver (too much information sent at one time); or part can be lost completely through fading and interference (which can reduce intelligibility of the complete message and make it difficult to guess, or even query clearly, the gaps). Note, too, how brevity also includes the avoidance of *unnecessary* repetitions.

The use of air space is otherwise very similar to good manners in ordinary conversation. Give the other fellow a chance to 'talk'. Be clear about what you are saying or asking. And do not butt in on other conversations (although there are obvious exceptions here, when 'good manners' dictates that you butt in at an appropriate point, not in the middle of a message).

As with all other 'operational techniques', it is practice and experience which counts in the end. No amount of 'book learning' can make a competent—and confident—radio operator. Too much wordage on what to do and what not to do, in fact, is probably more confusing than helpful. There are things to be learnt, particularly the codes used. They need to become a natural second language—and the use of a language cannot be learnt properly from the written word. It has to be listened to, and spoken (whether in telegraphy or code, in the case of 'radio language').

THE MORSE CODE

This is the original telegraphic code, subsequently adopted as an international radio code. Although generally referred to as the Morse Code, it does differ in some respects from the original (although this is only

of historic interest). It is a true international code, recognized by all countries, although there may be individual preferences for rendering of the numerals 9 and 0 (*see* alternatives in the list below).

A	di-dah	S	di-di-dit
B	dah-di-di-dit	T	dah
C	dah-di-dah-dit	U	di-di-dah
D	dah-di-dit	V	di-di-di-dah
E	dit	W	di-dah-dah
F	di-di-dah-dit	X	dah-di-di-dah
G	dah-dah-dit	Y	dah-di-dah-dah
H	di-di-di-dit	Z	dah-dah-di-dit
I	di-dit	1	di-dah-dah-dah-dah
J	di-dah-dah-dah	2	di-di-dah-dah-dah
K	dah-di-dah	3	di-di-di-dah-dah
L	di-dah-di-dit	4	di-di-di-di-dah
M	dah-dah	5	di-di-di-di-dit
N	dah-dit	6	dah-di-di-di-dit
O	dah-dah-dah	7	dah-dah-di-di-dit
P	di-dah-dah-dit	8	dah-dah-dah-di-dit
Q	dah-dah-di-dah	9	dah-dah-dah-dah-dit (*or* dah-dit)
R	di-dah-dit	0	dah-dah-dah-dah-dah (*or* long dah)

The following is the usual treatment of punctuation in Morse:

Question mark   dah-di-di-dah-dit
Full stop   di-dah-di-dah-di-dah
Comma, or exclamation mark   dah-dah-di-di-dah-dah
Stroke   dah-di-di-dah-dit

Note that a Morse message is commonly sent in abbreviated code language, rather than letter for letter, e.g. using the Q code or recognized abbreviations.

The following specific abbreviations also apply to Morse procedure:

$\overline{\text{AR}}$ (di-dah-di-dah-dit)   end of message
$\overline{\text{AS}}$ (di-dah-di-di-dit)   wait
$\overline{\text{CT}}$ (dah-di-dah-di-dah)   preliminary call
K   (dah-di-dah)   invitation to transmit
VA   (di-di-di-dah-di-dah)   end of work
dah-di-di-di-dah   break sign
di-di-di-di-di-di-di-dit   error

AMATEUR ABBREVIATIONS

The following simple code is widely used by amateurs and internationally recognized.

AA	Used after a question mark to request repetition of 'all after . . .'
AB	Used after a question mark to request repetition of 'all before . . .'
$\overline{\text{AR}}$	End of transmission
$\overline{\text{AS}}$	Wait, or stand by
BK	To interrupt a transmission in progress
BN	Used after a question mark to request repetition of 'all between . . . and . . .'
$\overline{\text{BT}}$	To separate address from text, or text from signature
C	Yes
CFM	Confirm, or I confirm
CL	I am closing my station
CQ	General call to all stations
DE	Used to separate the call-sign of the station called from that of the calling station
ER	Please transmit
IMI	Query, or repeat
K	No (or 'over' or 'go ahead' in American practice)
N	No
NIL	I have nothing to send you
NW	Now
OK	Agreed, or correct
R	Received
RPT	Repeat (or I repeat)
TFC	Traffic
W	Words
WA	Words after
WB	Words before

The following abbreviations of 'amateur radioese' are generally understood by all English-speaking enthusiasts.

ABT	About
ADR	Address
AGN	Again
ANI	Any
ANT	Antenna (aerial)
BA	Buffer amplifier
BC	Broadcast
BCI	Broadcast interference
BCL	Broadcast listener
BCNU	Be seeing you

BD	Bad
BFO	Beat frequency oscillator
BK	Break-in
BLV	Believe
BUG	Semi-automatic key
CANS	Headphones
CC	Crystal-controlled
CK	Check
CLD	Called
CNT	Cannot
CO	Crystal oscillator
CONDX	Conditions
CPSE	Counterpoise
CRD	Card
CUD	Could
CUAGN	See you again
CUL	See you later
CW	Continuous wave
DF	Direction finding
DR	Dear
DX	Long distance
ECO	Electron-coupled oscillator
ELBUG	Electronic key
ENUF	Enough
ES	And
FB	Fine business
FOC	First Class Operators' Club
FD	Frequency doubler
FM	Frequency modulation
FER	For
FONE	Telephone
FREQ	Frequency
GA	Go ahead, or good afternoon
GB	Goodbye
GD	Good day
GE	Good evening
GG	Going
GLD	Glad
GM	Good morning
GN	Good night
GND	Ground (earth)
GUD	Good
HAM	Amateur transmitter
HI	Laughter
HPE	Hope
HR	Here or hear
HRD	Heard
HV	Have
HVY	Heavy
HW	How
IARU	International Amateur Radio Union
II	Repetition signal
INPT	Input
LID	Poor operator
LSN	Listen
MNI	Many
MO	Master oscillator
MOD	Modulation
MSG	Message
MTR	Meter (or metres)
NBFM	Narrow band frequency modulation
ND	Nothing doing
NR	Number
OB	Old boy
OC	Old chap
OM	Old man
OP	Operator
OT	Old timer
PA	Power amplifier
PP	Push-pull
PSE	Please
PWR	Power
RAC	Rectified (raw) A.C.
RAOTA	Radio Amateur Old Timers' Association
RCVR	Receiver

RPRT	Report	U	You
RX	Receiver	UR	Your
SA	Say	VFO	Variable frequency oscillator
SED	Said	VY	Very
SIG	Signal	W	Watts
SKED	Schedule	WAC	Worked all Continents
SN	Soon	WID	With
SRI	Sorry	WKD	Worked
SSB	Single sideband	WKG	Working
STN	Station	WL	Will or well
SUM	Some	WUD	Would
SW	Short-wave	WX	Weather
SWL	Short-wave listener	XMTR	Transmitter
TFC	Traffic	XYL	Wife
TKS	Thanks	XTAL	Crystal
TMW	Tomorrow	YF	Wife
TNX	Thanks	YL	Young lady
TRI	Try	73	Best regards
TV	Television	88	Love and kisses
TVI	Television interference		
TX	Transmitter		

THE RST CODE

This is a short and simple code which may be interposed with 'radioese' to cover questions and answers on the quality of transmission—R for Readability, S for Signal strength and T for tone, each followed by a number designating quality, the higher the number the better the quality, e.g.

R1 Unreadable
R2 Barely readable (occasional words understood)
R3 Readable, but with considerably difficulty
R4 Readable, with very little difficulty
R5 Perfectly readable
S1 Signals very faint, barely heard
S2 Very weak signal
S3 Weak signal
S4 Fair signal strength
S5 Fairly good signal strength

S6 Good signal strength
S7 Moderately strong signals
S8 Strong signals
S9 Very strong signal
T1 Extremely rough hissing noise
T2 Very rough unmusical note
T3 Rough low-pitched *ac* note with trace of musicality
T4 Rather rough *ac* note, moderately musical
T5 Musically modulated note
T6 Modulated note, slight trace of whistle
T7 Good *dc* note, smooth ripple
T8 Good *dc* note, trace of ripple
T9 Pure *dc* note

It will be appreciated that the 'T' signals apply only to telegraphy. The 'Readability' and 'Signal Strength' parts of the code may be used either with telegraphy or telephony.

The following may also be appended to RST code answers:

X if the note appears to be crystal controlled
D if there appears to be drift
K if there are 'clicks'
C if there is 'chirp'

PHONETIC CODES

Since many letters sound very similar on telephony it is often necessary to spell out words or names, letter-by-letter, in phonetic substitutes. Again, to avoid possible confusion, standard phonetic substitutes should be used, not those devised on the spur of the moment! The following two standard phonetic codes are in widespread use and generally understood.

	ICAO code (*general to world radio services whose languages use the Roman alphabet*)	ARRL code (*used by radio amateurs in U.S.A. and Canada*)
A	ALFA	ADAM
B	BRAVO	BAKER
C	CHARLIE	CHARLIE
D	DELTA	DAVID

E	ECHO	EDWARD
F	FOXTROT	FRANK
G	GOLF	GEORGE
H	HOTEL	HENRY
I	INDIA	IDA
J	JULIETTE	JOHN
K	KILO	KING
L	LIMA	LEWIS
M	MIKE	MARY
N	NOVEMBER	NANCY
O	OSCAR	OTTO
P	PAPA	PETER
Q	QUEBEC	QUEEN
R	ROMEO	ROBERT
S	SIERRA	SUSAN
T	TANGO	THOMAS
U	UNIFORM	UNION
V	VICTOR	VICTOR
W	WHISKEY	WILLIAM
X	X-RAY	X-RAY
Y	YANKEE	YOUNG
Z	ZULU	ZEBRA

THE INTERNATIONAL Q CODE

The Q code was first introduced in 1912 as an international code for ship radio operators to enable them to communicate with shore stations in different countries without any language barrier. The code originally consisted of fifty three-letter signals prefixed by Q (i.e. 'Q' identified the code, the two following letters being the significant part of the signal). The code has subsequently been extended considerably in message coverage, both officially and unofficially (e.g. by signals adopted by amateurs to cover situations not embraced by the official code).

The following is an abridged list of Q signals most likely to be used, or heard, on amateur transmissions. Note that in the majority of cases a particular signal can be a question or an answer, i.e. the original signal transmitted as a question is repeated as an answer, with additional information added as appropriate.

QAM	What is the latest available meteorological observation for (place)? The observation made at (time) was . . .
QAP	Shall I listen for you (or for . . .) on——kc? Listen for me (or for . . .) on——kc
QAR	May I stop listening on the watch frequency for—minutes? You may stop listening on the watch frequency for—minutes
QBF	Have we worked before in this contest? We have worked before in this contest
QHM	I will tune from the high end of the band towards the middle (Used after a call or CQ.)
QIF	What frequency is . . . using? He is using—kc
QJA	Is my RTTY (1—tape, 2—M/S) reversed? It is reversed
QJB	Shall I use (1—TTY, 2—reperf)? (For RTTY use.) Use (1—TTY, 2—reperf)
QJC	Check your RTTY (1—TC, 2—auto head, 3—reperf, 5—Printer, 7—keyboard)
QJD	Shall I transmit (1—letters, 2—figs)? (For RTTY) Transmit (1—letters, 2—figs)
QJE	Shall I send (1—wide, 2—narrow, 3—correct) RTTY shift? Your RTTY shift is (1—wide, 2—narrow, 3—correct)
QJF	Does my RTTY signal check out OK? Your RTTY signal checks out OK
QJH	Shall I transmit (1—test tape, 2—test sentence) by RTTY? Transmit (1—test tape, 2—test sentence) by RTTY
QJI	Shall I transmit continuous (1—mark, 2—space) RTTY signal? Transmit continuous (1—mark, 2—space) signal
QJK	Are you receiving continuous (1—mark, 2—space, 3—mark bias, 4—space bias)? I am receiving continuous (1—mark, 2—space, 3—mark bias, 4—space bias)
QLM	I will tune for answers from the low end of the band toward the middle
QMD	I will tune for answers from my frequency down
QMH	I will tune for answers from the middle of the band toward the high end
QML	I will tune from answers from the middle of the band toward the low end
QMU	I will tune for answers from my frequency upward
QNJ	Can you copy me?

	Can you copy . . .——?
QNP	Unable to copy you Unable to copy——
QRA	What is the name of your station? The name of my station is . . .
QRB	How far approximately are you from my station? The approximate distance between our station is . . . nautical miles (or kilometres)
QRD	Where are you bound for and where are you from? I am bound for . . . from . . .
QRE	What is your estimated time of arrival at . . . (or over . . .) (place)? My estimated time of arrival at . . . (or over . . .) (place) is . . . hours
QRF	Are you returning to . . . (place)? I am returning to . . . (place) or Return to . . . (place)
QRG	Will you tell me my exact frequency (or that of . . .)? Your exact frequency (or that of . . .) is . . . kc. (or Mc.)
QRH	Does my frequency vary? Your frequency varies
QRI	How is the tone of my transmission? The tone of your transmission is . . . 1. good 2. variable 3. bad
QRJ	Are you receiving me badly? Are my signals weak? I am receiving you badly. Your signals are too weak
QRK	What is the intelligibility of my signals (or those of . . .)? The intelligibility of your signals (or those of . . .) is . . . 1. bad 2. poor 3. fair 4. good 5. excellent
QRL	Are you busy? I am busy (or I am busy with . . .). Please do not interfere
QRM	Are you being interfered with? (1. nil 2. slightly 3. moderately 4. severely 5. extremely)
QRN	Are you troubled by static? I am troubled by static (1. nil 2. slightly 3. moderately 4. severely 5. extremely)
QRO	Shall I increase transmitter power? Increase transmitter power
QRP	Shall I decrease transmitter power? Decrease transmitter power
QRQ	Shall I send faster?

	Send faster (. . . words per minute)
QRR	Are you ready for automatic operation? I am ready for automatic operation. Send at . . . words per minute
QRRR	Distress call signal for use by amateur cw and RTTY stations. To be used only in situations where there is danger to human life or safety
QRS	Shall I send more slowly? Send more slowly
QRT	Shall I stop sending? Stop sending
QRU	Have you anything for me? I have nothing for you
QRV	Are you ready? I am ready
QRW	Shall I inform . . . that you are calling him on . . . kc? Please inform . . . that I am calling him on . . . kc
QRX	When will you call me again? I will call you again at . . . hours (on . . . kc)
QRZ	Who is calling me? You are being called by . . . (on . . . kc)
QSA	What is the strength of my signals (or those of . . .)? The strength of your signals (or those of . . .) is . . . 1. scarcely perceptible 2. weak 3. fairly good 4. good 5. very good
QSB	Are my signals fading? Your signals are fading
QSD	Is my keying defective? Your keying is defective
QSG	Shall I send . . . messages at a time? Send . . . messages at a time
QSH	Are you able to home on your D/F equipment? I am able to home on my D/F equipment (on station . . .)
QSI	I have been unable to break in on your transmission
QSK	Can you hear me between your signals and if so can I break in on your transmission? I can hear you between my signals; break in on my transmission
QSL	Can you acknowledge receipt? I am acknowledging receipt
QSN	Did you hear me [or . . . (call sign)] on . . . kc? I did hear you [or . . . (call sign)] on . . . kc

QSO Can you communicate with . . . direct (or by relay)?
I can communicate with . . . direct (or by relay through . . .)

QSR Shall I repeat the call on the calling frequency?
Repeat your call on the calling frequency; did not hear you (or have interference)

QSS What working frequency will you use?
I will use the working frequency . . . kc

QST Calling all radio amateurs

QSU Shall I send or reply on this frequency (or on . . . kc)?
Send or reply on this frequency (or on . . . kc)

QSV Shall I send a series of V's on this frequency (or . . . kc)?
Send a series of V's on this frequency (or . . . kc)

QSW Will you send on this frequency (or on . . . kc)?
I am going to send on this frequency (or on . . . kc)

QSX Will you listen to . . . (call sign(s)) on . . . ko?
I am listening to . . . (call sign(s)) on . . . kc

QSY Shall I change to transmission on another frequency?
Change to transmission on another frequency (or on . . . kc)

QSZ Shall I send each word or group more than once?
Send each word or group twice (or . . . times)
Cancel message number . . .

QTC How many messages have you to send?
I have . . . messages for you (or for . . .)

QTR What is the correct time?
The correct time is . . . hours

QTS Will you send your call sign for tuning purposes or so that your frequency can be measured now (or at . . . hours) on . . . kc?
I will send my call sign for tuning purposes or so that my frequency may be measured now (or at . . . hours) on . . . kc

QTU What are the hours during which your station is open?
My station is open from . . . to . . . hours

QTV Shall I stand guard for you on the frequency of . . . kc (from . . . to . . . hours)?
Stand guard for me on the frequency of . . . kc (from . . . to hours)

QTX Will you keep your station open for further communication with me until further notice (or until . . . hours)
I will keep my station open for further communication with you until further notice (or until . . . hours)

QUA Have you news of . . . (call sign)?
Here is news of . . . (call sign)

QUE Can you use telephony in . . . (language), with interpreter if necessary; if so, on what frequencies?
I can use telephony in . . . (language) on . . . kc

QUH Will you give me the present barometric pressure at sea level?
The present barometric pressure at sea level is . . . (units)

QUK Can you tell me the condition of the sea observed at . . . (place or co-ordinates)?
The sea at . . . (place or co-ordinates) is . . .
I will keep my station open for further communication with you until further notice (or until . . . hours)

These signals are often used in a slightly different sense by amateurs, namely as specific signals, viz:

QRA location
QRG frequency
QRI bad note
QRM interference from other stations
QRN interference from atmospherics or local electrical apparatus
QRO high power
QRP low power
QRT close down
QRX stand by
QSB fading
QSD bad sending
QSL verification card
QSO radio contact
QSP relay message
QSY change of frequency
QTH location

APPENDIX I

AMATEUR TRANSMITTING LICENCES

It is a statutory requirement that before anyone can operate an amateur radio station in Great Britain he (or she) must first obtain a suitable licence from the Ministry of Posts and Telecommunications. The basic requirements for obtaining a licence are:

1. The applicant must be over 14 years old.
2. The applicant must supply proof of British nationality. (Foreign amateurs who wish to operate in the U.K., such as during a temporary visit, can apply for a special G5 three-letter call-sign and Sound Licence C).
3. The applicant must pass a written technical examination.
4. The applicant must also pass a Morse Code test in order to qualify for a 'full' licence, i.e. Amateur (Sound) Licence A. No Morse test is required to obtain an Amateur (Sound) Licence B, or an Amateur (Television) Licence.

Amateur (Sound) Licence A covers operation on Morse, speech and radio teleprinter (RTTY) in all the appropriate amateur bands—*see* Table 11. Annual fee £3.

Amateur (Sound) Licence B covers speech transmission only, restricted to amateur frequencies above 144 MHz. Annual fee £3.

Amateur (Sound) Licence C is available to foreign amateurs for use in the U.K.

Amateur (Television) Licence—covers television operation at frequencies above 144 MHz. Annual fee £3.

Amateur (Sound Mobile) Licence—is available to applicants already holding either an A or B licence for mobile use of their equipment (e.g. in cars). Additional fee £1.50. The same restrictions apply in the case of B licence holders.

Amateur (Maritime) Licence—covers amateur operation on British ships in the following frequency bands:

7, 14, 21, 28 and 144 MHz; and 21 GHz

Table 11. Amateur Frequency Bands (U.K.)

Frequency Band MHz	Class(es) of Emission	Power: Max dc[1] Input	Power: rf Output[2]	Notes
1·8		10 watts	26⅔ watts	This band shared by other services[3] RTTY must not be used on this band
3·5 – 3·8	(i) Telegraphy by on-off keying	150 watts	400 watts	This band shared by other services
7 – 7·10 14 – 14·35 21 – 21·45	(ii) Telephony, double sideband (iii) Telephony, single sideband (reduced carrier)	150 watts	400 watts	
28 – 29·7 70·025 – 70·7	(iv) Telephony, single sideband (full carrier)	50 watts	133⅓ watts	This band shared by other services[3] can be withdrawn on immediate notice
144 – 145	(v) Telephony, single sideband (suppressed carrier)	150 watts	400 watts	These bands shared by other services specific (aircraft band), spot frequencies must be avoided
145 – 146 425 – 429 432 – 450 1215 – 1325 2300 – 2450 3400 – 3475 5650 – 5850	(vi) Telegraphy by frequency shift keying (vii) Telegraphy by on-off keying of frequency modulating AF, or FM emission (viii) Telephony	150 watts	400 watts	These bands shared by other services[3]
10000 – 10500 21000 – 22000		150 watts	400 watts	

2390 – 2400 5700 – 5800 10050 – 10450	(i) Telegraphy by on-off keying of pulsed carrier (with or without modulating AF) (ii) Telephony, amplitude modulated pulses	25 watts (mean) 2·5 kilowatts (peak)	—	These bands shared by other services[3]
21150 – 21850	(iii) Telephony, width modulated pulses	25 watts (mean) 2·5 kilowatts (peak)	—	

Notes.

1. *dc* input power is the total direct current power input to (i) the anode circuits of the valve(s); or (ii) any other device energizing the aerial circuit.
2. *rf* output peak envelope power for Telephony single sideband, reduced carrier or suppressed carrier only. Alternatively peak power for these emissions may be determined by the peak envelope power under linear conditions.
3. It is implied that the amateur service is secondary and is operated on the condition that it does not cause interference to the other services.

The Technical Examination

The written examination which has to be passed before any type of transmitting licence can be obtained is not frightening. It is merely designed to ensure that would-be operators of an amateur radio station have a basic knowledge of the technical conditions involved, and particularly their responsibilities. Part I of the examination syllabus is confined to a study of 1—Licensing Conditions and 2—Transmitter Interference. The examination paper contains two questions on Part I subjects, one invariably dealing with licensing conditions and the other dealing with transmitter interference. Both must be answered.

Part II of the syllabus deals with technology, although on a fairly elementary basis. In the examination eight questions are set on separate technical subjects, but only six have to be attempted. This choice can be very encouraging to anyone 'weak' on a particular technical subject!

The whole written examination lasts three hours. A pass mark must be obtained in *both* parts to qualify. It is thus no good being strong on 'practice' (Part I) and weak on 'theory' (Part II), with the hope that one will balance the other.

The *Morse test* is taken separately, and must be passed *within* the twelve months *before* the licence is applied for (i.e. Sound Licence A). To pass this test the applicant must prove himself (or herself) capable of sending and receiving plain language in Morse at an average speed of twelve words per minute.

Examinations for the Radio Amateur Licences are set twice a year, usually in May and December, by the City and Guilds of London Institute, Electrical and Telecommunications Branch, 76 Portland Place, London W.1. It is not necessary to attend at this particular address as the examination can be taken simultaneously throughout the country at various local centres by arrangement with the Local Educational Authority.

The Morse test is specifically a Post Office (practical) examination. It can be taken at various times throughout the year at the Post Office Headquarters in London; or at the following places:

POST OFFICE COAST STATIONS:
Amlwch, Anglesey
Broadstairs, Kent
Connel, Argyll

Highbridge, Somerset
Ilfracombe, Devon
Stonehaven, Kincardineshire
Stranraer, Wigtownshire
Mablethorpe, Lincoln
Penzance, Cornwall
Ventnor, Isle of Wight
Wick, Caithness
Whitley Bay, Northumberland

RADIO SURVEYOR'S OFFICES:
Belfast
Cardiff
Edinburgh
Falmouth
Glasgow
Hull
Liverpool
Newcastle-upon-Tyne
Southampton

HEAD POST OFFICES:
Birmingham
Cambridge
Derby
Leeds
Manchester

Charges involved are £1.50 for the written examination (with a small additional fee usual if taken at a local centre); and £2.00 for the Morse test.

Preparing for the Examination

The amount of study required to pass the Radio Amateur's Examination can, of course, vary enormously with individuals—and particularly with their initial knowledge of radio and radio technology. Certainly previous knowledge is helpful, although the syllabus subjects will still need careful study in order to be sure of a 'pass' standard, particularly in Part I. On the other hand, it is quite possible to 'start from scratch' and complete the examination course successfully in a matter of months,

by attending evening classes at a local Technical College or College of Further Education, or even by taking a correspondence course.

Self-tuition is also perfectly feasible, particularly if the individual concerned already has some background knowledge of radio technology and an enthusiasm for the subject. Membership of the Radio Society of Great Britain will be especially helpful in this case, as this Society publishes a comprehensive study guide called *The Radio Amateurs' Examination Manual* and other invaluable books and booklets. The Society also sponsors the transmission by amateurs throughout the country of Morse practice lessons intended for beginners.

Local amateur radio clubs can also be a further source of 'personal' contact and help; and a number also organize special lectures for beginners.

Learning the Morse Code and Morse operating technique is almost purely a matter of practice. This may be covered by college courses, or again can be self-taught. There are numerous publications available on this subject, also gramophone records and tapes for training in receiving Morse signals.

The standard required to pass the Morse test is:

1. Thirty-six words with an average length of five letters per word must be received in three minutes. Up to four errors are permitted.

2. Thirty-six words with an average length of five letters per word must be sent in three minutes. Up to four corrections may be made in sending; but no uncorrected errors are permitted.

3. Ten groups of five figures must be received in one and a half minutes. Two errors are permitted.

4. Ten groups of five figures must be sent in one and a half minutes. Up to two corrections can be made in sending; but no uncorrected errors are permitted.

Plan for Beginners

It is usually best for beginners to plan to take the written examination first. Then, subject to achieving a pass, to take the Morse test at the earliest suitable opportunity thereafter. There is no reason why Morse should not be studied at the same time as the written syllabus, rather than regarding it as a 'separate' subject. If Morse is studied first, and the examination taken and passed, there is always the possibility that a subsequent failure in the written examination can result in more than

twelve months elapsing before the written examination can be taken again, and passed. In this case the Morse test would have to be taken again to come within the twelve month interval required.

Note. Licences issued describe in detail the conditions which apply to the operation of an amateur radio station covered by that particular licence. Extracts of these conditions are sent with the publication *How to Become a Radio Amateur*, available free on request from the Ministry of Posts and Telecommunications.

SYLLABUS OF THE RADIO AMATEUR EXAMINATION

The examination is a PASS examination consisting of a single question paper of three hours duration. Each paper is divided into two parts. Part I contains only two questions, each of them compulsory. These questions will be drawn from items 1 and 2 of the syllabus. Part II consists of eight questions, drawn from the remaining items of the syllabus, of which six only should be attempted.

Candidates are expected to achieve a pass in each of the Parts separately and failure in either Part entails failure in the examination as a whole.

SYLLABUS:

PART I

1. *Licensing Conditions*

Conditions (terms, provisions and limitations) laid down by the Minister in the Amateur (Sound) Licence, covering the purpose for which the transmitters may be used; types of signals permissible; types of emission; power; frequency control and measurements; avoidance of interference to other stations, particularly in bands shared with other services; qualifications of operators; log keeping and use of call signs.

2. *Transmitter Interference*

Frequency stability. Avoidance of harmonic radiation and of interference by shock excitation; use of key click filters and other means of preventing spurious emissions. Dangers of over modulation. Devices for reducing interference with near-by radio and television receivers.

PART II

3. *Elementary Electricity and Magnetism*

Elementary theory of electricity; conductors and insulators; units; Ohm's law; resistors in series and parallel. Power; Permanent magnets and electro-magnets and their use in radio work. Primary cells; Self and mutual

inductance; types of inductors used in receiving and transmitting circuits. Capacitance; construction of various types of capacitors and their arrangements in series and/or parallel.

4. *Elementary Alternating Current Theory*
Alternating current and voltages. Alternating current theory incorporating circuits with inductance, capacitance and resistance. Impedance, resonance, coupled circuits, acceptor and rejector circuits. The transformer.

5. *Thermionic Valves and Semi-conductors*
Characteristics and essential construction of transistors, semi-conductor diodes, thermionic diodes, triodes and multi-electrode valves. Use of semi-conductor devices and valves as oscillators, amplifiers, detectors and frequency-changers. Distortion; harmonics. Push-pull; power rectification: stabilization and smoothing; typical power packs for low-power transmitters and receivers.

6. *Radio Receivers*
Typical receivers; principles and operation of T.R.F. and superheterodyne receivers. *c.w.* reception. Interference caused by receivers.

7. *Low power transmitters*
Oscillator circuits; use of quartz crystal to control oscillators. Frequency multipliers, power amplifiers. Methods of keying transmitters. Methods of modulation and types of emission in current use.

8. *Propagation*
Nature and propagation of radio waves. Ionospheric and tropospheric conditions and their effect on propagation. Relationship between wavelength, frequency and velocity of propagation.

9. *Aerials*
Common types of receiving and transmitting aerials. Transmission lines. Directional systems. Aerial couplings to lines and transmitters. Matching.

10. *Measurements*
Measurement of frequency. Operation of simple frequency meters (including crystal controlled types); use of verniers and other interpolation methods. Artificial aerials and their use for lining up transmitters. Measurement of current and voltage at audio and radio frequencies. Measurement of power input to the final stage(s) of a transmitter. Use of cathode-ray oscilloscope for the examination and measurement of waveform.

APPENDIX II

AMATEUR RADIO CALL SIGNS

BRITISH call signs:

G for England
GB special stations and exhibitions
GC for Channel Islands
GD for Isle of Man
GI for Northern Ireland
GM for Scotland
GW for Wales

English call signs by date:

G2 followed by two letters	1920–39
G3	1937–38
G4	1938–39
G5	1921–39
G6	1921–39
G8	1936–37
G2 followed by three letters	pre-1939
G5	1966 onwards (Sound Licence C)
G6	/T for Amateur Television Licence from 1964 on
G8	1964 onwards (Sound Licence B)

The following is the years in which G3 followed by three letters sequences began:

G3A	1946
G3D	1947
G3G	1950
G3J	1952
G3M	1957
G3W	1967
G3Y	1969

WORLD CALL SIGNS

A2 Botswana
AC3 Sikkim
AC4 Tibet
AC Bhutan
AP Bangladesh
AP West Pakistan
BV Formosa
BY China
CE Chile
CE9, FB8Y, KC4, LA, LU-Z, OR4, UA1, VKØ, VP8, ZL5, 8J Antarctica
CEØA Easter Island
CEØZ Juan Fernandez Archipelago
CEØX San Felix
CM, CO Cuba
CN2, 8, 9 Morocco
CP Bolivia
CR3 Portuguese Guinea
CR4 Cape Verde Islands
CR5 Principe, Sao Thome
CR6 Angola
CR7 Mozambique
CR8 Portuguese Timor
CR9 Macao
CT1 Portugal
CT2 Azores
CT3 Madeira Islands
CX Uruguay
DJ, DK, DL, DM Germany
DU Philippine Islands
EA Spain
EA6 Balearic Islands
EA8 Canary Islands
EA9 Ifni
EA9 Rio de Oro
EA9 Spanish Morocco
EAØ Spanish Guinea
EI Republic of Ireland
EL Liberia
EP Iran
ET3 Ethiopia
F France
FB8X Amsterdam and St. Paul
FB8W Crozet Island
FB8X Kerguelen Islands
FC (unofficial) Corsica
FG7 Guadeloupe
FH8 Comoro Islands
FK8 New Caledonia
FL8 French Somaliland
FM7 Martinique
FO8 Clipperton Island
FO8 French Oceania
FP8 St. Pierre and Miquelon Islands
FR7 Glorioso Islands
FR7 Juan de Nova
FR7 Reunion
FR7 Tromelin
FS7 Saint Martin
FW8 Wallis and Futuna Islands
FY7 French Guiana and Inini
G England
GC Guernsey and Dependencies
GC Jersey Island
GD Isle of Man
GI Northern Ireland
GM Scotland
GW Wales
HA, HG Hungary
HBØ Lichtenstein
HB Switzerland
HC Ecuador
HC8 Galapagos Islands

HH Haiti
HI Dominican Republic
HK Colombia
HKØ (See KS4B)
HKØ Bajo Nuevo
HKØ Malpelo Island
HKØ San Andres and Providencia
HL, HM Korea
HP Panama
HR Honduras
HS Thailand
HV Vatican
HZ, 7Z Saudi Arabia
I, IT1 Italy
IS1 Sardinia
JA, JH, KA Japan
JT1 Mongolia
JW Svalbard
JX Jan Mayen
JY Jordan
K, W United States of America
KA1 (See KG6I)
KB6 Baker, Howland and American Phoenix Islands
KC4 Navassa Island
KC6 Eastern Caroline Islands
KC6 Western Caroline Islands
KG4 Guantanamo Bay
KG6 Guam
KG6I, KA1 Marcus Island
K66R, S, T Mariana Islands
KG61, KA1 Bonin and Volcano Islands
KH6 Hawaiian Islands
KH6 Kure Island
KJ6 Johnston Island
KL7 Alaska
KM6 Midway Islands
KP4 Puerto Rico
KP6 Palmyra Group, Jarvis Island
KR6, 8 Ryukyu Islands
KS4B, HKØ Serrana Bank and Roncador Cay
KS4 Swan Islands
KS6 American Samoa
KV4 Virgin Islands
KW6 Wake Island
KX6 Marshall Islands
KZ5 Canal Zone
LA Norway
LU Argentina
LX Luxembourg
LZ Bulgaria
M1, 9A1 San Marino
MP4B Bahrein
MP4Q Qatar
MP4M, VS9O Sultanate of Muscat and Oman
MP4D, T Trucial Oman
OA Peru
OD5 Lebanon
OE Austria
OH, OF Finland
OHØ Aland Islands
OK Czechoslovakia
ON Belgium
OX, XP Greenland
OY Faroe Islands
OZ Denmark
PAØ, PI1 Netherlands
PJ Netherlands Antilles
PJ Sint Maarten
PX Andorra
PY Brazil
PYØ Fernando de Noronha
PYØ St. Peter & St. Paul's Rocks
PYØ Trinidade and Martim Vaz Islands
PZ1 Surinam
SK, SL, SM Sweden
SP Poland

ST2 Sudan
SU Egypt
SV Crete
SV Dodecanese
SV Greece
TA Turkey
TF Iceland
TG Guatemala
TI Costa Rica
TI9 Cocos Island
TJ Cameroon
TL Central African Republic
TN Congo Republic
TR Gabon Republic
TT Chad Republic
TU Ivory Coast
TY Dahomey Republic
TZ Mali Republic
UA, UV, UW1-6, UN1 Eu. Russian S.F.S.R.
UA1 Franz Josef Land
UA2 Kaliningradsk
UA, UV, UW9, Ø Asiatic R.S.F.S.R.
UB5, UT5, UY5 Ukraine
UC2 White Russian S.S.R.
UD6 Azerbaijan
UF6 Georgia
UG6 Armenia
UH8 Turkoman
UI8 Uzbek
UJ8 Tadzhik
UL7 Kazakh
UM8 Kirghiz
UO5 Moldavia
UP2 Lithuania
UQ2 Latvia
UR2 Estonia
VE, VO Canada
VK Australia
VK Lord Howe Island
VK Willis Islands
VK9 Christmas Island
VK9 Cocos Islands
VK9 Nauru Island
VK9 Norfolk Island
VK9 Papua Territory
VK9 Territory of New Guinea
VKØ Heard Island
VKØ Macquarie Island
VO Newfoundland, Labrador
VP1 British Honduras
VP2K Anguilla
VP2A Antigua, Barbuda
VP2V British Virgin Islands
VP2D Dominica
VP2G Granada and Dependencies
VP2M Montserrat
VP2K St. Kitts, Nevis
VP2L St. Lucia
VP2S St. Vincent and Dependencies
VP5 Turks and Caicos Islands
VP7 Bahama Islands
VP8 Falkland Islands
VP8, LU-Z South Georgia Islands
VP8, LU-Z South Orkney Islands
VP8, LU-Z South Sandwich Islands
VP8, LU-Z, CE9 South Shetland Islands
VP9 Bermuda Islands
VQ1 Zanzibar
VQ8 Agalega and St. Brandon
VQ8 Mauritius
VQ8 Rodriguez Island
VQ9 Aldabra Islands
VQ9 Chagos
VQ9 Desroches
VQ9 Farguber
VQ9 Seychelles
VR1 British Phoenix Islands

VR1 Gilbert and Ellice Islands and Ocean Island
VR2 Fiji Islands
VR3 Fanning and Christmas Islands
VR4 Solomon Islands
VR5 Tonga Islands
VR6 Pitcairn Island
VS5 Brunei
VS6 Hong Kong
VS9, A, P, S Aden and Socotra
VS9K Kamaran Islands
VS9M, 8Q Maldive Islands
VU Andaman and Nicobar Islands
VU India
VU Laccadive Islands
W, K United States of America
XE, XF Mexico
XF4 Revilla Gigedo
XP (See OX)
XT Voltaic Rep.
XU Cambodia
XN (See 3W8)
XW8 Laos
XZ2 Burma
YA Afghanistan
YB Indonesia
YI Iraq
YJ New Hebrides
YK Syria
YN, YNØ Nicaragua
YO Rumania
YS Salvador
YU Yugoslavia
YV Venezuela
YVØ Aves Island
ZA Albania
ZB2 Gibraltar
ZC4 (see 5B4)
ZD3 Gambia
ZD5 Swaziland
ZD7 St. Helena
ZD8 Ascension Island
ZD9 Tristan da Cunha and Gough Islands
ZE Rhodesia
ZF1 Cayman Islands
ZK1 Cook Islands
ZK1 Manihiki Islands
ZK2 Niue
ZL Auckland Isl. and Campbell Isl.
ZL Chatham Islands
ZL Kermadec Islands
ZL New Zealand
ZM7 Tokelau (Union) Islands
ZP Paraguay
ZS1, 2, 4, 5, 6 South Africa
ZS2 Prince Edward and Marion Islands
ZS3 Southwest Africa
3A Monaco
3V8 Tunisia
3W8, XV Vietnam
3Y Bouvet Island
4S7 Ceylon
4U I.T.U. Geneva
4W Yemen
4X, 4Z Israel
5A Libya
5B4, ZC4 Cyprus
5H3 Tanganyika
5N2 Nigeria
5R8 Malagasy Rep.
5T Mauritania
5U7 Niger Rep.
5V Togo
5W1 Western Samoa
5X5 Uganda
5Z4 Kenya
6O1, 2, 6 Somali Rep.
6W8 Senegal Rep.

6Y Jamaica
7G1 Rep. of Guinea
7P Lesotho
7Q Nyasaland
7X Algeria
7Z, HZ Saudi Arabia
8F, YB Indonesia
8J (See CE9)
8P Barbados
8Q (See VS9M)
8R Guyana
8Z4 Saudi Arabia/Iraq Neutral Zone
8Z5, 9K3 Kuwait/Saudi Arabia Neutral Zone
9A1, M1 San Marino
9G1 Ghana
9H1 Malta
9J2 Zambia
9K2 Kuwait
9K3, 8Z5 Kuwait/Saudi Arabia Neutral Zone
9L1 Sierra Leone
9M2 Malaya
9M4 Singapore
9M6 Sarawak
9M8 Sabah
9N1 Nepal
9Q5 Rep. of Congo
9U5 Burundi
9X5 Rwanda
9Y4 Trinidad and Tobago

INTERNATIONAL PREFIXES

AAA-ALZ	United States of America
AMA-AOZ	Spain
APA-ASZ	Pakistan
ATA-AWZ	India
AXA-AXZ	Commonwealth of Australia
AYA-AZZ	Argentine Republic
BAA-BZZ	China
CAA-CEZ	Chile
CFA-CKZ	Canada
CLA-CMZ	Cuba
CNA-CNZ	Morocco
COA-COZ	Cuba
CPA-CPZ	Bolivia
CQA-CRZ	Portuguese Overseas Provinces
CSA-CUZ	Portugal
CVA-CXZ	Uruguay
CYA-CZZ	Canada
DAA-DTZ	Germany
DUA-DZZ	Republic of the Philippines
EAA-EHZ	Spain
EIA-EJZ	Ireland
EKA-EKZ	Union of Soviet Socialist Republics
ELA-ELZ	Liberia
EMA-EOZ	Union of Soviet Socialist Republics
EPA-EQZ	Iran
ERA-ERZ	Union of Soviet Socialist Republics
ESA-ESZ	Estonia
ETA-ETZ	Ethiopia
EUA-EWZ	Bielorussian Soviet Socialist Republic
EXA-EZZ	Union of Soviet Socialist Republics
FAA-FZZ	France and French Community
GAA-GZZ	United Kingdom

HAA-HAZ	Hungarian People's Republic
HBA-HBZ	Switzerland
HCA-HDZ	Ecuador
HEA-HEZ	Switzerland
HFA-HFZ	People's Republic of Poland
HGA-HGZ	Hungarian People's Republic
HHA-HHZ	Republic of Haiti
HIA-HIZ	Dominican Republic
HJA-HKZ	Republic of Colombia
HLA-HMZ	Korea
HNA-HNZ	Iraq
HOA-HPZ	Republic of Panama
HQA-HRZ	Republic of Honduras
HSA-HSZ	Thailand
HTA-HTZ	Nicaragua
HUA-HUZ	Republic of El Salvador
HVA-HVZ	Vatican City State
HWA-HYZ	France and French Community
HZA-HZZ	Saudi Arabia
IAA-IZZ	Italy and Mandated Territories
JAA-JSZ	Japan
JTA-JVZ	Mongolian People's Republic
JWA-JXZ	Norway
JYA-JYZ	Jordan
JZA-JZZ	West New Guinea
KAA-KZZ	United States of America
LAA-LNZ	Norway
LOA-LWZ	Argentine Republic
LXA-LXZ	Luxembourg
LYA-LYZ	Lithuania
LZA-LZZ	People's Republic of Bulgaria
MAA-MZZ	United Kingdom
NAA-NZZ	United States of America
OAA-OCZ	Peru
ODA-ODZ	Lebanon
OEA-OEZ	Austria
OFA-OJZ	Finland
OKA-OMZ	Czechoslovakia
ONA-OTZ	Belgium
OUA-OZZ	Denmark
PAA-PIZ	Netherlands
PJA-PJZ	Netherlands Antilles
PKA-POZ	Republic of Indonesia
PPA-PYZ	Brazil
PZA-PZZ	Surinam
QAA-QZZ	(Service abbreviations)
RAA-RZZ	Union of Soviet Socialist Republics
SAA-SMZ	Sweden
SNA-SRZ	People's Republic of Poland
SSA-SSM	United Arab Republic
SSN-STZ	Sudan
SUA-SUZ	United Arab Republic
SVA-SZZ	Greece
TAA-TCZ	Turkey
TDA-TDZ	Guatemala
TEA-TEZ	Costa Rica
TFA-TFZ	Iceland
TGA-TGZ	Guatemala
THA-THZ	France and French Community
TIA-TIZ	Costa Rica
TJA-TJZ	Republic of Cameron
TKA-TKZ	France, and French Community
TLA-TLZ	Central African Republic
TMA-TMZ	France, French Community

TNA-TNZ	Republic of Congo (Brazzaville)
TOA-TQZ	France, French Community
TRA-TRZ	Republic of Gabon
TSA-TSZ	Tunisia
TTA-TTZ	Republic of Chad
TUA-TUZ	Republic of the Ivory Coast
TVA-TXZ	France, French Community
TYA-TYZ	Republic of Dahomey
TZA-TZZ	Republic of Mali
UAA-UQZ	Union of Soviet Socialist Republics
URA-UTZ	Ukrainian Soviet Socialist Republic
UUA-UZZ	Union of Soviet Socialist Republics
VAA-VGZ	Canada
VHA-VNZ	Commonwealth of Australia
VOA-VOZ	Canada
VPA-VSZ	British Overseas Territories
VTA-VWZ	India
VXA-VYZ	Canada
VZA-VZZ	Commonwealth of Australia
WAA-WZZ	United States of America
XAA-XIZ	Mexico
XJA-XOZ	Canada
XPA-XPZ	Denmark
XQA-XRZ	Chile
XSA-XSZ	China
XTA-XTZ	Republic of the Upper Volta
XUA-XUZ	Cambodia
XVA-XVZ	Viet-Nam
XWA-XWZ	Laos
XXA-XXZ	Portuguese Overseas Provinces
XYA-XZZ	Burma
YAA-YAZ	Afghanistan
YBA-YHZ	Republic of Indonesia
YIA-YIZ	Iraq
YJA-YJZ	New Hebrides
YKA-YKZ	Syria
YLA-YLZ	Latvia
YMA-YMZ	Turkey
YNA-YNZ	Nicaragua
YOA-YRZ	Roumanian People's Republic
YSA-YSZ	Republic of El Salvador
YTA-YUZ	Yugoslavia
YVA-YYZ	Venezuela
YZA-YZZ	Yugoslavia
ZAA-ZAZ	Albania
ZBA-ZJZ	British Overseas Territories
ZKA-ZMZ	New Zealand
ZNA-ZOZ	British Overseas Territories
ZPA-ZPZ	Paraguay
ZQA-ZQZ	British Overseas Territories
ZRA-ZUZ	Republic of South Africa
ZVA-ZZZ	Brazil
2AA-2ZZ	Great Britain
3AA-3AZ	Monaco
3BA-3FZ	Canada
3GA-3GZ	Chile
3HA-3UZ	China
3VA-3VZ	Tunisia
3WA-3WZ	Viet-Nam
3XA-3XZ	Guinea
3YA-3YZ	Norway
3ZA-3ZZ	People's Republic of Poland

4AA-4CZ	Mexico
4DA-4IZ	Republic of the Philippines
4JA-4LZ	Union of Soviet Socialist Republics
4MA-4MZ	Venezuela
4NA-4OZ	Yugoslavia
4PA-4SZ	Ceylon
4TA-4TZ	Peru
4UA-4UZ	United Nations
4VA-4VZ	Republic of Haiti
4WA-4WZ	Yemen
4XA-4XZ	State of Israel
4YA-4YZ	International Civil Aviation Organization
4ZA-4ZZ	State of Israel
5AA-5AZ	Libya
5BA-5BZ	Republic of Cyprus
5CA-5GZ	Morocco
5HA-5IZ	Tanzania
5JA-5KZ	Colombia
5LA-5MZ	Liberia
5NA-5OZ	Nigeria
5PA-5QZ	Denmark
5RA-5SZ	Malagasy Republic
5TA-5TZ	Islamic Republic of Mauretania
5UA-5UZ	Republic of the Niger
5VA-5VZ	Togolese Republic
5WA-5WZ	Western Samoa
5XA-5XZ	Uganda
5YA-5ZZ	Kenya
6AA-6BZ	United Arab Republic
6CA-6CZ	Syria
6DA-6JZ	Mexico
6KA-6NZ	Korea
6OA-6OZ	Somalia
6PA-6SZ	Pakistan
6TA-6UZ	Sudan
6VA-6WZ	Republic of the Senegal
6XA-6XZ	Malagasy Republic
6YA-6YZ	Jamaica
6ZA-6ZZ	Liberia
7AA-7IZ	Indonesia
7JA-7NZ	Japan
7QA-7QZ	Malawi
7RA-7RZ	Algeria
7SA-7SZ	Sweden
7TA-7YZ	Algeria
7ZA-7ZZ	Saudi Arabia
8AA-8IZ	Indonesia
8JA-8NZ	Japan
8SA-8SZ	Sweden
8TA-8YZ	India
8ZA-8ZZ	Saudi Arabia
9AA-9AZ	San Marino
9BA-9DZ	Iran
9EA-9FZ	Ethiopia
9GA-9GZ	Ghana
9HA-9HZ	Malta
9IA-9JZ	Zambia
9KA-9KZ	Kuwait
9LA-9LZ	Sierra Leone
9MA-9MZ	Malaysia
9NA-9NZ	Nepal
9OA-9TZ	Republic of the Congo (Leopoldville)
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